NASA MANNED SPACECRAFT CENTER

FINAL PROGRESS REPORT

CONTRACT NO. NAS9-7320

ESB REPORT NO. E-6-70

ESB INCORPORATED
EXIDE MISSILE AND ELECTRONICS DIVISION
RALEIGH, NORTH CAROLINA

6 FEBRUARY 1970

NASA CR 108317

NASA Final Progress Report
Contract No. NAS9-7320
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1.0 SCOPE OF CONTRACT

The NASA Manned Spacecraft Center, General Research Procurement Branch, Houston, Texas Contract NAS9-7320 was with the Exide Missile and Electronics Division of ESB Incorporated, Raleigh, North Carolina. The contract was entered into on 30 June 1967. The contract scope was to design, develop, document, fabricate, and deliver one silver oxide-zinc storage battery power supply in accordance with NASA Work Statement, Exhibit "A" dated 22 June 1967 and attachments "B" and "C" - Reliability and Quality Assurance Requirements. During the period of performance six modifications to the contract have been incorporated.

There were two design goals for the contract: (1) battery weight of 1.5 pounds with a specified maximum of 2.0 pounds, and (2) temperature cycling between -40°F and +160°F with a specified range of -40°F to +140°F. The final battery weight was 1.78 pounds and the units successfully met the -40°F to +160°F design goal.

2.0 PROGRESS SUMMATION

At the beginning of the contract a program plan was initiated in an effort to schedule the total program. This program plan was revised and resubmitted as required in order to plan and schedule work on the contract. The progress of the program can best be summed up by listing those major tasks of the overall plan.

2.1 <u>Cell Development Program</u>. - Two generations of test cells were manufactured and tested during this program. The second generation of test cells was designed after the first generation of cells had seen approximately 8 discharge cycles. From the cell development program a final cell design was established and then incorporated into the battery design.

2.2 Heater System Design. - During this phase, the heat loss and gain characteristics of the battery were investigated as related to the thermal vacuum requirements. Design of the heater blanket, thermostat and insulation were accomplished and incorporated into the final design specification.

2.3 Experimental Battery Design and Test. - The battery chassis design and seal were completed, along with packaging of the six sealed cells within the chassis. Batteries were tested to the environmental and thermal vacuum tests. Determinations were made during this phase which led to final design of the prototype units.

2.4 Prototype Battery Design and Test. - Units were tested to the thermal vacuum test requirements during this phase, and one unit completed the 14-day thermal vacuum test successfully. This battery design was that incorporated into the unit sent to NASA to fulfill the contract.

2.5 Qual Sample Fabrication. - Drawings and specifications were initiated to control the fabrication of the deliverable unit to those characteristics incorporated into the prototype unit which successfully completed the requirements. The qual sample was delivered to NASA on 30 January 1970.

3.0 SCHEDULE/MILESTONE STATUS

Initiation of Contract	30 June 1967
Cell Development	30 January 1968 (Complete)
Experimental Battery Design	15 August 1968 (Complete)
Prototype Battery Design	15 August 1969 (Complete)
Qualification Battery Delivery	30 January 1970

4.0 SUMMARY OF TESTS

4.1 Cell Development. - Thirty-five cells were manufactured for evaluation of cell design for the battery. A summary of the design variations is shown in Table I.

TABLE I

TEST CELL DESIGN VARIATIONS

BASIC DESIGN

Positive Plates - 6 - 0.020" thick - 78 gm/in^3 density
Negative Plates - 7 - 0.030" thick - Formulation 91/7/2 (see Table II)
Separator - 2 layers Fibrous Sausage Casing (FSC)
Electrolyte - 40% KOH

Design No.	Test Cells	Special Design Features
1	-1, -2, -3	Basic design.
2	-4, -5, -6	Same as 1 except negatives 5 - 0.030" thick and 2 0.018" thick, separator 1 layer EM-476 polypropylene - 5 layers 193-PUDO cellophane.
3	-7, -8, -9	Same as 2 except 4 layer of RAI-341 in place of cellophane and electrolyte 31% KOH and no EM-476.
4	-10, -11, -12	Same as 2 except 1 layer of RAI-341 replacing 1 of 5 cellophane and no EM-476.
5	-13, -14, -15	Same as 2 except 5 layers of RAI-110 replacing cellophane and no EM-476.
6	-16, -17, -18	Same as 2 except 2 layers of RAI-110 replacing 2 of 5 cellophane layers and no EM-476.
7	-19, -20, -21	Same as 2 except positive plates contain 3% PbO and have density of 69 gm/in^3 - separator has 2 layers fibrous sausage casing and 1 layer RAI-110 in place of 5 layers of cellophane and no EM-476.
8	-23, -24, -25 -26	Same as 2 except positive contains 1% Pd and has density of 69 gm/in^2 - 2 layers of fibrous sausage casing and 1 layer of EM-476.
9	-27, -28, -29 -30	Same as 8 except 1 layer of nylon cloth replacing 1 layer of EM-476.
10	-31, -32, -33	Same as 8 except no Pd in positive plates.
11	-34, -35, -36	Same as 1 except 1% emulphogene BC-840 in negative plates.

The test cell procedure was as follows:

NASA HOUSTON TEST CELL PROCEDURE

I. Activate cells with 31-40% KOH. (See item IV below.)

   a. Record dry weight (2 place decimal).

   b. Record date and time of activation.

   c. Record wet weight (2 place decimal).

   d. Record volume of KOH (presently undetermined).

II. Discharge Test. - Constant current of 500 milliamps to 1.50 volts (always read and cut load when 1.50 is passed and not during the first part of the discharge). Use fixed resistance load for all tests so each cell is discharged under the same conditions.

III. Cell Identification. - Cells are identified for test purposes as 347-1, 347-2, etc.

IV. Activation. -

	% KOH
a. S/N 347-1 thru 347-6 and 347-10 thru 347-36	SS-200 Grade 40 (40%)
b. 347-1 thru 347-9	SS-200 Grade 31

V. Charge Procedure. - Charge cells at 0.35 ampere to 2.0 volts or 20 hours, whichever is shorter.

VI. Test Procedure. - Cells shall be tested to the following procedure.

   a. Cell 347-1 (control) 2L FSC

      1. Activate per instructions.

      2. Stand - Min. 48 hours - Allow to gas.

      3. Charge per procedure.

      4. Install non-vent plug - Pilot Plant.

5. Stabilize cell at 70-80°F (record temperature) for minimum of 4 hours.

6. Discharge per procedure; record voltage and current on data sheet at 30 seconds, 60 seconds, 3 minutes, 5 minutes, each 1/2 hour thereafter till end voltage, including cutoff time.

7. Charge per procedures within one day after discharge.

8. Stabilize cell at 45-50°F (record temperature) for a minimum of 7 hours.

9. Discharge as above (6).

10. Charge as above (7).

11. Stabilize cell at 35-40°F (record temperature) for a minimum of 7 hours.

12. Discharge as above (6).

13. Stand at 80°F ±5°F for 15 days.

14. Charge unit as above (7) on 16th day.

15. Discharge as above (6).

16. Cycle cell-charge (7) - discharge (6) for an additional 6 cycles for a total of 10 cycles and complete within a 1 month period. Temperature for the 6 cycles to be 70-90°F.

b. Cell 347-2 (control) 2L FSC

1. Conduct sequences a 1 thru a 4.

2. Put in storage at 80 ±5°F for 30 days.

3. On 31st day, charge per procedures.

4. 1 day after charge, discharge per a 6.

5. Repeat items b 2, b 3, and b 4 for 2 more cycles - total of 3 discharge - storage - cycles.

6. After 3rd discharge, put in storage at 80 ±5°F for 15 days.

7. On the 16th day, charge per procedures.

8. 1 day after charge, discharge per a 6.

9. Cycle cell - storage - charge - discharge per b 6, b 7, b 8, for 7 cycles - total of 10 cycles.

c. 347-3 (control) 2L FSC

1. Conduct sequences a 1 thru a 4.

2. Put in storage at 140°F for 2 weeks.

3. One day after, charge at room temperature.

4. Stabilize at 160°F for 18 hours.

5. Discharge at 160°F at 0.5 ampere for 0.5 hr.

6. Put in +45°F chamber for 24 hours.

7. Discharge at +45°F at 0.5 ampere for 0.5 hr.

8. Repeat items c 4, c 5, c 6, c 7, for a period of 14 days (7 at 45°F - 7 at 160°F).

   Do this within a 14 day period. On the last discharge run to an end voltage of 1.50 vd.

d. 347-4 1L EM-476, 5L 193-PUDO

1. Conduct sequences a 1 thru a 4.

2. Cycle cell for a total of 10 cycles per a 6 and a 7 at 140°F discharge and room temperature charge. Complete within a 30 day period. Record date of time when cell is at 140°F.

e. 347-5 1L EM-476, 5L 193-PUDO

1. Conduct sequences a 1 thru a 4.

2. Put on 1 year storage varying the temperature between the temperature extremes of -20°F to 90°F with a normal temperature of room temperature.

3. Discharge per a 6.

f. 347-6 1L EM-476, 5L 193-PUDO

Conduct test for cell 347-1 (a).

g., h., i. 347-7, 347-8, 347-9

To be given at a later date.

j. 347-10 1L RAI-341, 4L 193-PUDO

1. Conduct sequences a 1 thru a 4.

2. Stabilize cell at 160°F for 112 hours.

3. Discharge at room temperature immediately afterward per a 6.

4. Put on 6 months storage at 90°F.

5. Discharge per a 6.

k. 347-11 1L RAI-341, 4L 193-PUDO

1. Conduct sequences a 1 thru a 4.

2. Cycle 10 times at room temperature per a 6 and a 7, within a 60-day period. (5 cycles per month.)

l. 347-12 1L RAI-341, 4L 193-PUDO

Run test (a) (347-1)

m. 347-13 5L RAI-110

Run test (a) 347-1

n. 347-14 5L RAI-110

Run test (c) 347-3

o. 347-15 5L RAI-110

Run test (b) 347-2

p. 347-16 2L RAI-110, 3L 193-PUDO

Run test (a) 347-1

q. 347-17 2L RAI-110, 3L 193-PUDO

Run test (b) 347-2

r. 347-18 2L RAI-110, 3L 193-PUDO

Run test (c) 347-3

s. 347-19 2L FSC PB069

Run test (a) 347-1

t. 347-20 2L FSC PB069

Run test (b) 347-2

u. 347-21 2L FSC PB069

Run test (c) 347-3

v. 347-34 2L FSC BC840C

Run test (a) 347-1

w. 347-35 2L FSC BC840C

Run test (b) 347-2

x. 347-36 2L FSC BC840C

Run test (a) 347-3

S/N of Model 347 Cells Involved	Sequence	Cycle	Profile
		F	Charge* - install non-vent plug.
-1	a	F	Discharge at room temperature**
-6		2	Charge - Discharge at 45/50°F
-7		3	Charge - Discharge at 35/40°F
-12		4	Charge
-13			Stand 15 days at 80 ±5°F
-16		4	Topping Charge*** - Discharge at room temp
-19		5	Charge - Discharge at room temperature.
		6	Same as Cycle 5.
-26		7	Same as Cycle 5.
-30		8	Same as Cycle 5.
-33		9	Same as Cycle 5.
-34		10	Same as Cycle 5.
		Complete Cycles 4 through 10 within 1 month	
-2	b	F	Charge - install non-vent plug.
-8			Stand 30 days at 80 ±5°F
-15		F	Topping Charge - Discharge at room temp.
-17		2	Charge - Stand 30 days at 80 ±5°F
-20		2	Topping Charge - Discharge at room temp.
-23		3	Charge - Stand 30 days at 80 ±5°F.
-27		3	Topping Charge - Discharge at room temp.
-31		4	Charge - Stand 15 days at 80 ±5°F
-35		4	Topping Charge - Discharge at room temp.
		5	Same as Cycle 4.
		6	Same as Cycle 4.
		7	Same as Cycle 4.
		8	Same as Cycle 4.
		9	Same as Cycle 4.
		10	Same as Cycle 4.

			Profile
-3	c	F	Charge - install non-vent plug.
-9			Stand two weeks at 140°F.
-14		F.1	Topping Charge - Stabilize 18 hrs. at 160°F.
-18		F.2	Discharge 1/2 hour at standard rate at 160°F.
-21		F.3	Place immediately in +45°F leave 24 hrs.
-24		F.4	Discharge 1/2 hour at std. rate at +45°F.
-28		F.5	Stabilize at 160°F for 18/22 hours.
-32		F.6	Repeat steps F.2 through F.5.
-36		F.7	Repeat steps F.2 through F.5.
		F.8	Repeat steps F.2 through F.5.
		F.9	Repeat steps F.2 through F.5.
		F.10	Repeat steps F.2 through F.5.
		F.11	Repeat steps F.2 and F.3.
		F.12	Discharge to end point (see**) at +45°F.

Steps F.2 through F.12 to be completed in 14 days.

S/N of Model 347 Cells Involved	Sequence	Cycle	Profile
-10	j	F	Charge - install non-vent plug. Stand 112 hours at 160°F.
		F	Discharge at room temperature.
		2	Charge - stand 6 months at 90°F.
		2	Topping Charge - Discharge at room temp.
- 4	d	F	Charge - install non-vent plug.
-29		F	Discharge at 140°F.
		2	Charge at room temperature.
		2	Discharge at 140°F.
		3	Same as Cycle 2.
		4	Same as Cycle 2.
		5	Same as Cycle 2.
		6	Same as Cycle 2.
		7	Same as Cycle 2.
		8	Same as Cycle 2.
		9	Same as Cycle 2.
		10	Same as Cycle 2.
			Complete within 1 month.
- 5	e	F	Charge - install non-vent plug. Stand 1 year varying temperature between minus 20°F and +90°F with an average temperature of +70°F.
		F	Topping Charge - Discharge at room temp.
-11	k	F	Charge - install non-vent plug.
-25		F	Discharge at room temperature.
		2	Charge at room temperature.
		2	Discharge at room temperature.
		3	Same as Cycle 2.
		4	Same as Cycle 2.
		5	Same as Cycle 2.
		6	Same as Cycle 2.
		7	Same as Cycle 2.
		8	Same as Cycle 2.
		9	Same as Cycle 2.
		10	Same as Cycle 2.
			Complete within 60 days.

(*) Charge at 0.35 ampere to 2.00 volts or 20 hours whichever occurs first. All charge at room temperature. CAUTION: These are sealed cells - NEVER exceed 2.00 volts.

(**) Discharge through constant resistance of 3.20 ohms at temperature indicated in profile. Record time to 1.50 volts, record time and stop discharge at 1.40 volts.

(***) Charge at 0.35 ampere to 2.00 volts - see CAUTION above.

A 3.0 ohms constant resistance was calculated on anticipated voltage to provide an average current of 500 milliamperes over the total discharge. Less capacity was withdrawn at the upper plateau voltage resulting in a somewhat lower average current. In all cases, however, the average was within 5% of the 500 milliamperes requirement. Typical charge-discharge data is shown in Tables II and III. The test cell weights and electrolyte volume are as shown in Table IV.

TABLE II

CHARGE DATA ON MODEL 347 TEST CELLS

Cell No. (See Table III)	Hours On Charge*	Ampere-Hours Input
347-1	20.8	7.3
347-2	20.8	7.3
347-3	20.8	7.3
347-4	20.8	7.3
347-5	20.8	7.3
347-10**	20.0	7.0
347-11	20.8	7.3
347-12**	20.0	7.0
347-13**	17.2	6.0
347-14**	18.0	6.3
347-15**	18.9	6.6
347-16	20.0	7.0
347-17	20.0	7.0
347-18	20.6	7.2
347-19**	20.0	7.0
347-20**	20.0	7.0
347-21**	20.0	7.0
347-34**	20.2	7.1
347-35**	20.7	7.3
347-36**	20.2	7.1

(*) Charge Procedure: 0.35 ampere to 2.00 volts or 20 hours, whichever occurred first.

(**) These cells reached 2.00 volts - the remaining units were terminated at 20 hours (or slightly more) without reaching 2.00 volts.

TABLE III

DISCHARGE DATA ON MODEL 347 TEST CELLS

Cell No.	Resistive Load (Ohms)	Average Current (Amps)	Ampere-Hours To 1.50 Volts
347-1	3.2	0.475	6.0
347-6	3.2	0.495	2.4
347-11	3.2	0.475	4.6
347-12	3.2	0.475	4.1
347-13	3.2	0.495	4.1
347-16	3.2	0.505	4.6
347-19	3.2	0.495	5.5
347-34	3.2	0.515	2.0

TABLE IV

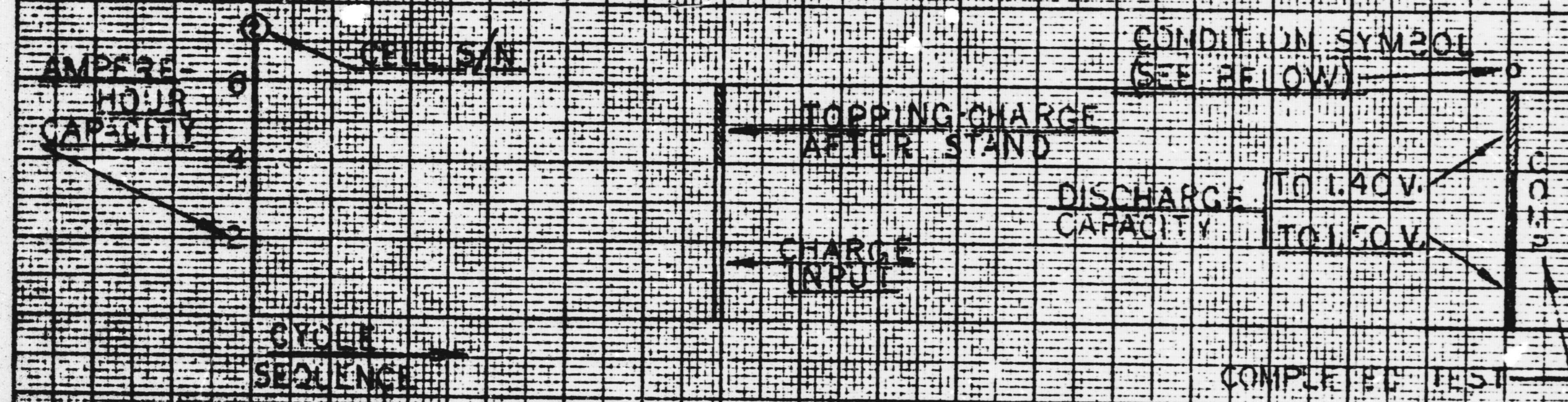
TEST CELL WEIGHTS AND ELECTROLYTE VOLUME

Cell Design	Mean Dry Wt. (Grams)	Mean Electrolyte Added (C.C.)	Mean Wet Wt. (Grams)
1	72.8	16	95.2
2	73.5	15-3/4	95.6
4	73.0	15-3/4	95.1
5	73.1	14	92.5
6	73.3	15	94.4
7	70.4	16-3/4	93.9
11	73.9	16-1/2	97.1

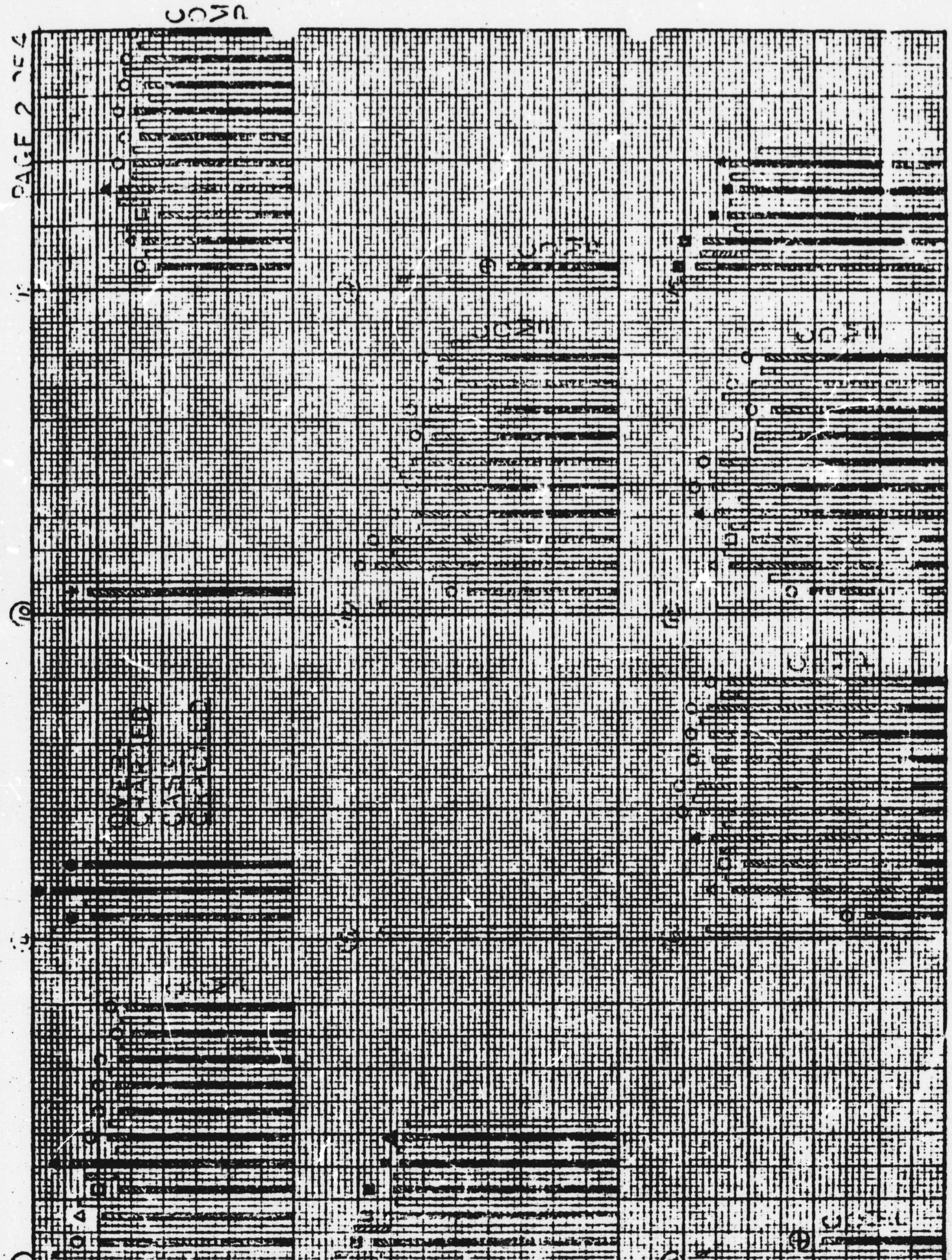
An error in testing was committed whereby S/N 4 was overcharged well beyond the gassing point causing a crack in the cell case and electrolyte loss. This cell was removed from the test program. Cell S/N's 20 and 21 shorted following second and first cycle charge, respectively. These units represented Design 7 where 3% PbO had been added to the positive plates. All cells containing lead shorted early in life due to adversely affecting the separator. Test cell capacities for the 35 test cells are summarized in Table V.

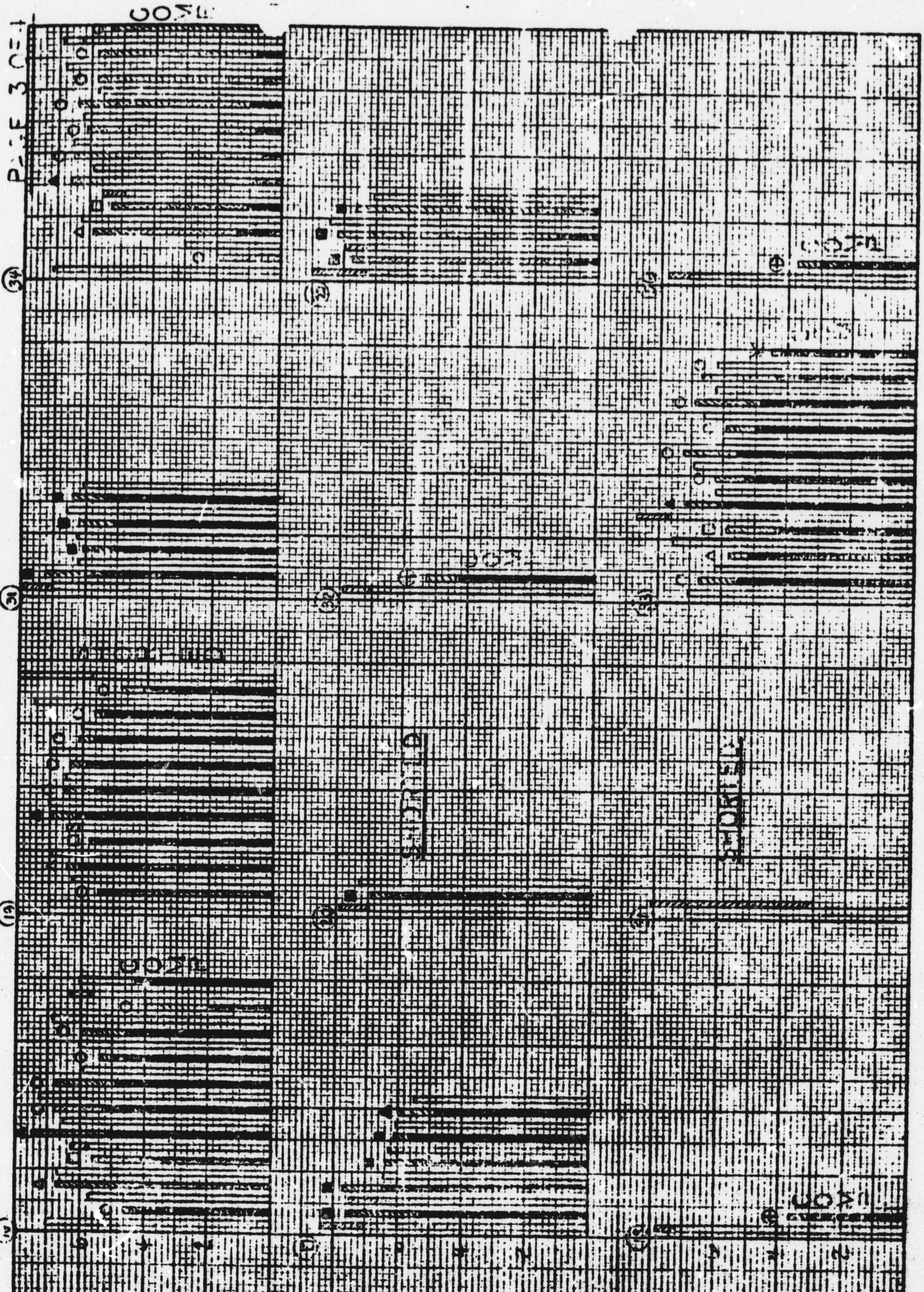
TABLE V - TEST CELL CAPACITIES PAGE 1 OF 4

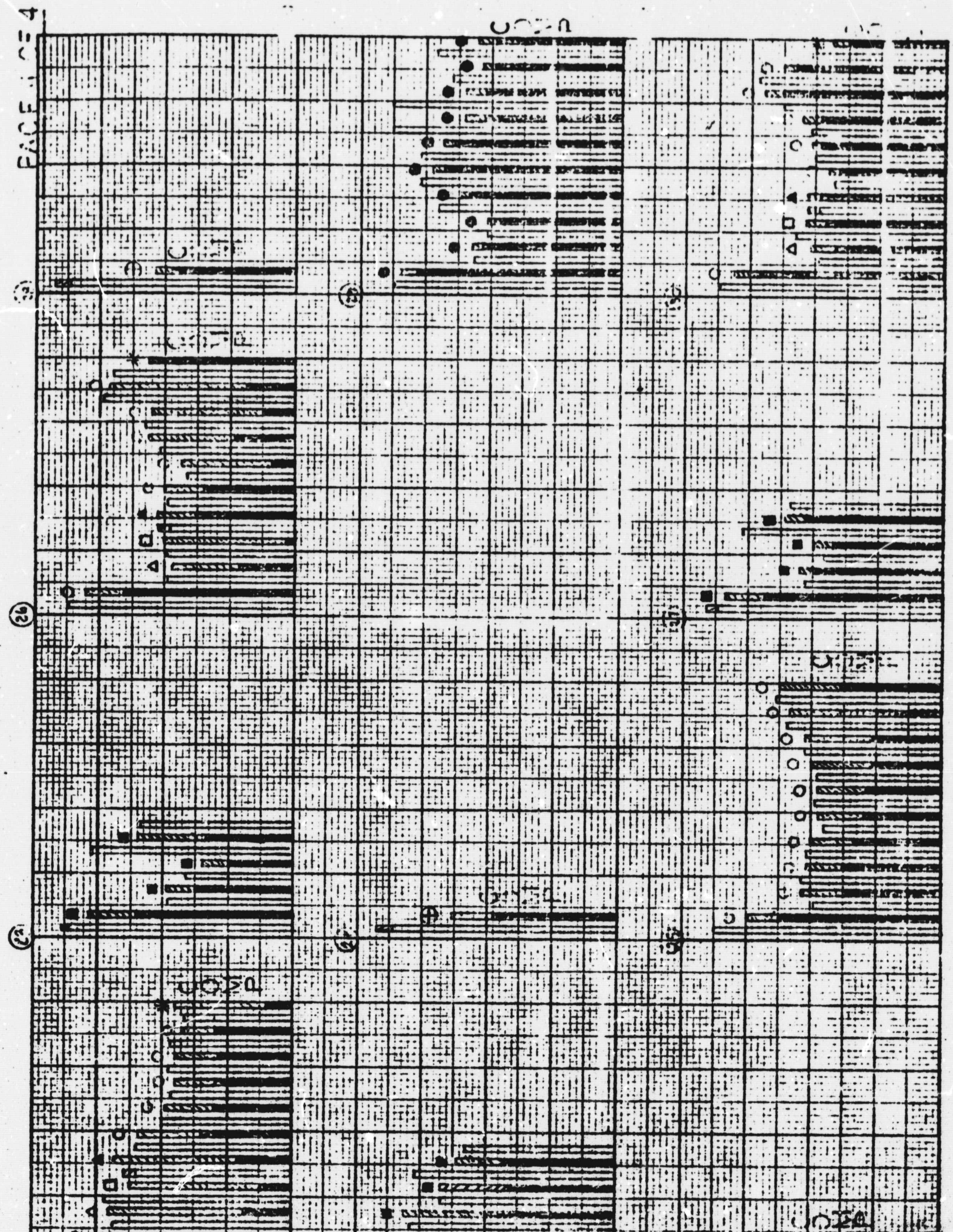
CODE FOR PAGES 2, 3 & 4 OF TABLE V



DISCHARGE CONDITION	SYMBOL
ROOM TEMP.	○
45°F.	△
35°F.	□
140°F.	●
R.T. AFTER 15 DAY STAND AT 80°F.	▲
R.T. " 30 DAY " " 80°F.	■
R.T. " 1/2 HOUR " " 100°F.	+
ALTERNATING 1/2 HOUR [illegible] CHARGES AT 160 & 45°F. AFTER [illegible] AT 140°F.	⊕
25 [illegible] [illegible] 4 [illegible] AH.	✳







After completion of their respective scheduled electrical tests, cells 3, 11, 18, and 36 were subjected to vibration tests. The vibration test was conducted as follows:

VIBRATION TEST ON CELLS

Cell No. 3 OCV - 1.56 (prior to testing)
Cell No. 11 OCV - 1.84 (prior to testing)
Cell No. 18 OCV - 1.57 (prior to testing)
Cell No. 36 OCV - 1.57 (prior to testing)

1st test cells No. 3 and 11 were vibrated as follows:

Sinusoidal
5-10 cps 0.20 in da (41 sec.)
10-26 cps ±1 g (57.5 sec.)
26-56 cps 0.03 in da (46 sec.)
56-2000 cps ±5 g (215.5 sec.)
5 cps-2KC-5cps for 6 min. in each axis.

2nd test cells No. 3 and 11 were vibrated as follows:

Random - 5g rms for 25 minutes
10 cps 0.01 g^2/cps
10-75 cps linear increase to 0.14 g^2/cps; 75-200 cps constant 0.14 g^2/cps, 200-2000 cps linear decrease to 0.0082 g^2/cps. See attached graph. Tested 25 minutes in X and Y axis.

3rd test cells No. 3 and 11 were vibrated as follows:

Random - 12.3 grms for 5 minutes
10 cps at 0.10 g^2/cps
10-75 cps linear increase to 0.14 g^2/cps, 75-200 cps constant 0.14 g^2/cps, 200-2000 cps linear decrease to 0.0082 g^2/cps. See attached graph. Tested five minutes in each of three axis (Y-Z-X)

4th test cells No. 18 and 36 were vibrated as follows:

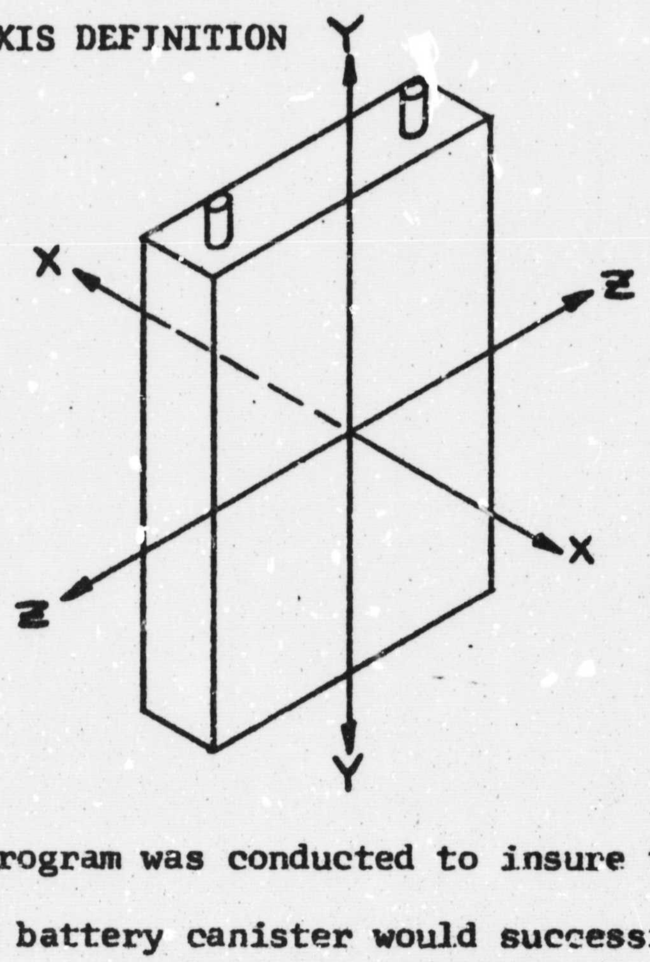
Random - 18.4 grms for 5 minutes
10 cps at 0.01 g^2/cps
10-75 cps linear increase to 0.14 g^2/cps, 75-200 cps constant 0.14 g^2/cps, 200-2000 cps linear decrease to 0.0082 g^2/cps. See attached graph. Tested five minutes in all three axis.

Comments for each set of test cells is outlined below:

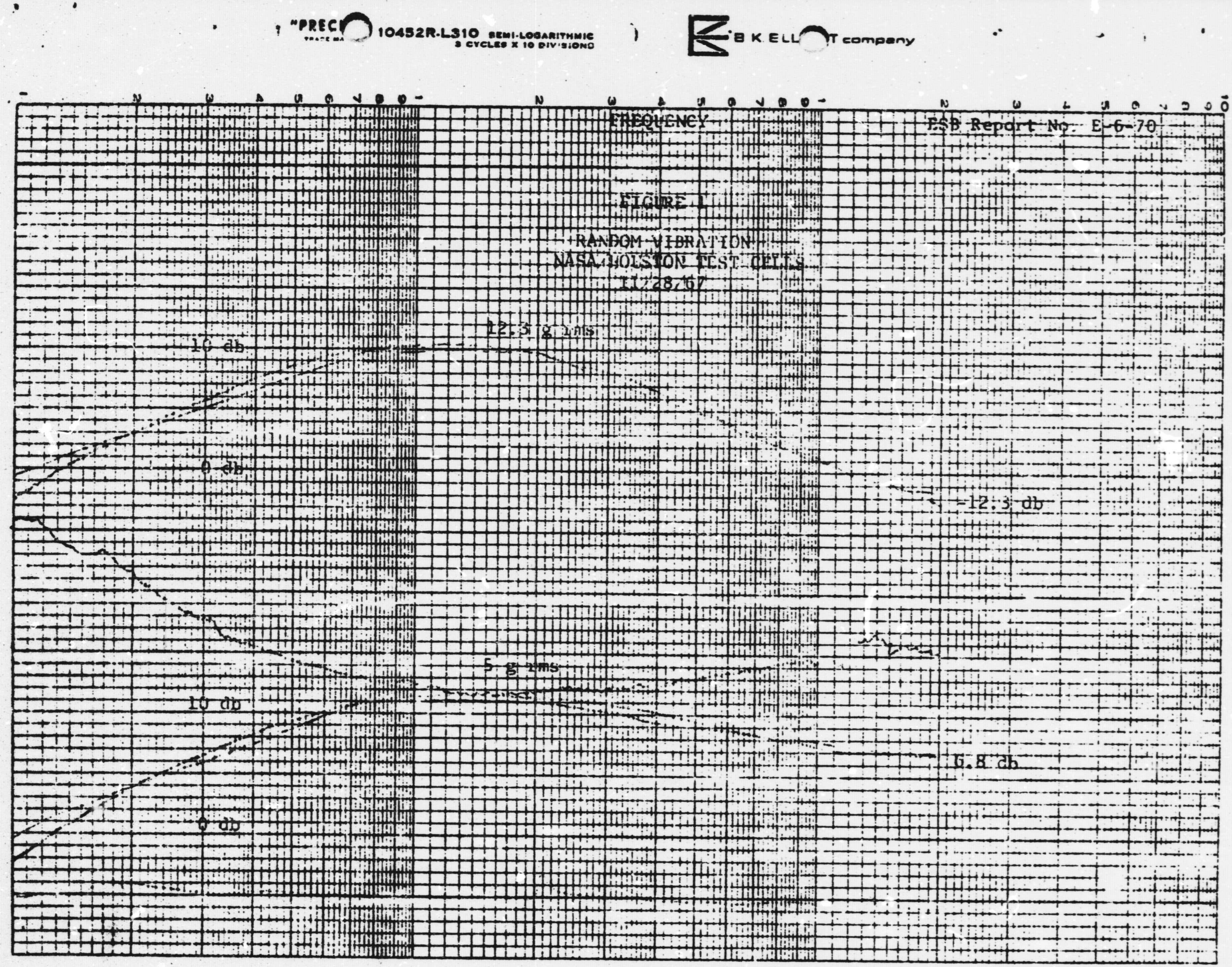
1st Test Cells -	Vibration not bad in any of the three axis. No movement of cell pack observed during vibration. OCV at completion of test same as OCV prior to test.
2nd Test Cells	Vibration not bad in the two axis tested. No indication of cell damage. OCV same as at start.
3rd Test Cells	This test is the most detrimental test to the cells. No indication of cell damage. OCV same as at start.
4th Test Cells	Test was run at one and one half times required level (12.3 to 18.4 grms). No detrimental affects in cells. No. 36 had free KOH and good amount of ZnO wash throughout cell.

The axis definition of the above tests was as follows:

AXIS DEFINITION



The vibration test program was conducted to insure that the cell oriented outermost in the battery canister would successfully pass the required vibration specification. Subsequent post-mortem of the cells vibrated showed no damage attributable to vibration. A frequency versus "G" level graph (Figure 1) is shown as a typical random vibration curve.


"PRECI 10452R-L310 SEMI-LOGARITHMIC
3 CYCLES X 10 DIVISIONS
B K ELL T company
FREQUENCY
FIGURE 1
RANDOM VIBRATION
NASA/HOLSTON TEST CELLS
11/28/67
12.3 g rms
10 db
0 db
-12.3 db
5 g rms
10 db
0 db
6.8 db

After completion of the first generation test cells, a design review was held and designs 1, 4, 6, and 10 were considered best. A second generation of test cells was then established to optimize the design. The second generation test cell variation are as shown in Table VI. These cells were tested to the test plan of Table VII.

TABLE VI

SECOND GENERATION TEST CELL DESIGN VARIATIONS

BASIC DESIGN

Positive plates -6- 0.020" thick - 78 gms/in^3 density

Negative plates -7- 0.030" thick - 91% ZnO, 7% HgO, 2% TFE

Separator - 2 layers of FSC

Electrolyte - 40% KOH

Design No.	Test Cells	Special Design Features
12	-37, -38, -39	Basic design except -37 will have 5 center negatives and 2 end negatives. Separator system for all 3 cells will be 1 layer of RAI-110 beside positive plate and 4 layers of 193-PUDO. Cell No. -37 will have 4% HgO in negative plates.
13	-40, -41, -42	Basic design except positive plate density to be 69 gms/in^3 and half negatives (5 + 2). 4% HgO to be used in negative plates for -40.
14	-43, -44, -45	Basic design except 1 layer of RAI-110 beside positive plate and half negatives. 4% HgO in cell -43 negative plate.
15	-46, -47, -48	Basic design with 6 positive and 5 + 2 negative. 69 gms/in^3 density and 1 layer nylon cloth, 5 layers of 193-PUDO. Cell -46 to have 4% HgO in negative plates.

TABLE VII

TEST PLAN

(SECOND GENERATION TEST CELLS)

S/N of Model 347 Cells Involved	Cycle	Profile
	F	Charge* - install non-vent plug.
-37	F	Discharge at room temperature**
thru	2	Charge - Discharge at 45/50°F.
	3	Charge - Discharge at 35/40°F.
	4	Charge
-48	4	Discharge at room temperature.
	5	Charge - Discharge at room temperature.
	6	Same as Cycle 5.
	7	Same as Cycle 5.
	8	Same as Cycle 5.
	9	Same as Cycle 5.
	10	Same as Cycle 5.

Complete cycles 4 through 10 within 1 month.

(*) Charge at 0.35 ampere to 2.00 volts or 20 hours whichever occurs first. All charging at room temperature.

CAUTION: These are sealed cells - NEVER exceed 2.00 volts.

(**) Discharge through constant resistance of 3.20 ohms at temperature indicated in profile. Record time to 1.50 volts, record time and stop discharge at 1.40 volts.

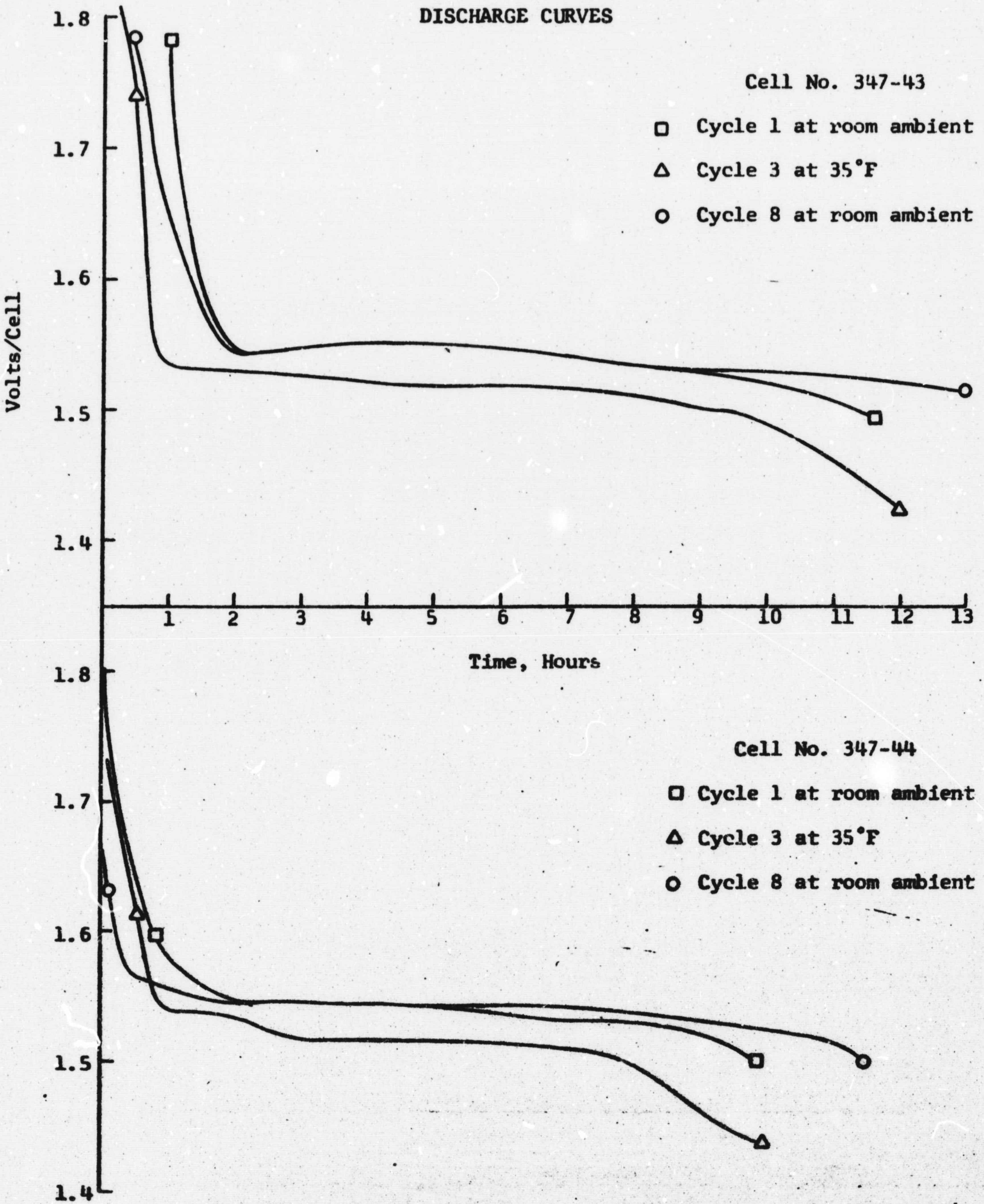
After completion of the two generations of test cells, cells representing each type design were post-mortemed. From the test cell discharge data and the post-mortem of the cells, it was determined that the test cells representing a separator system of two layers of fibrous sausage casing and one layer of RAI-110 was the optimum design. Test cells 43, 44 and 45 represented this design. Cells containing 7% HgO had negative grids that were more brittle than those with 4% HgO with no appreciable gassing in either of the cells with thevarying percentages of HgO. Curves showing the voltage characteristics of the selected cells are shown in Figure 2. In summary, the cell design is:

- 13 plate element
- sealed cell construction
- 1 layer RAI-110, 2 layers of fibrous sausage casing per ESB MS-230.
- Retainer per ESB MS-237, - Viskon S-250 cm - 3005X
- Negative Mix - 94% ZnO, 2% TFE, 4% HgO
- Positive Plate 78 gms/in^3 - DP Process
- Cell Weight (wet) 95 gms.
- Cell Length - 0.72 inch.
- Cell Width - 1.76 inches.
- Cell Height - 2.60 inches.

A summary of the discharge capacities for the second generation test cells is shown in Table VIII.

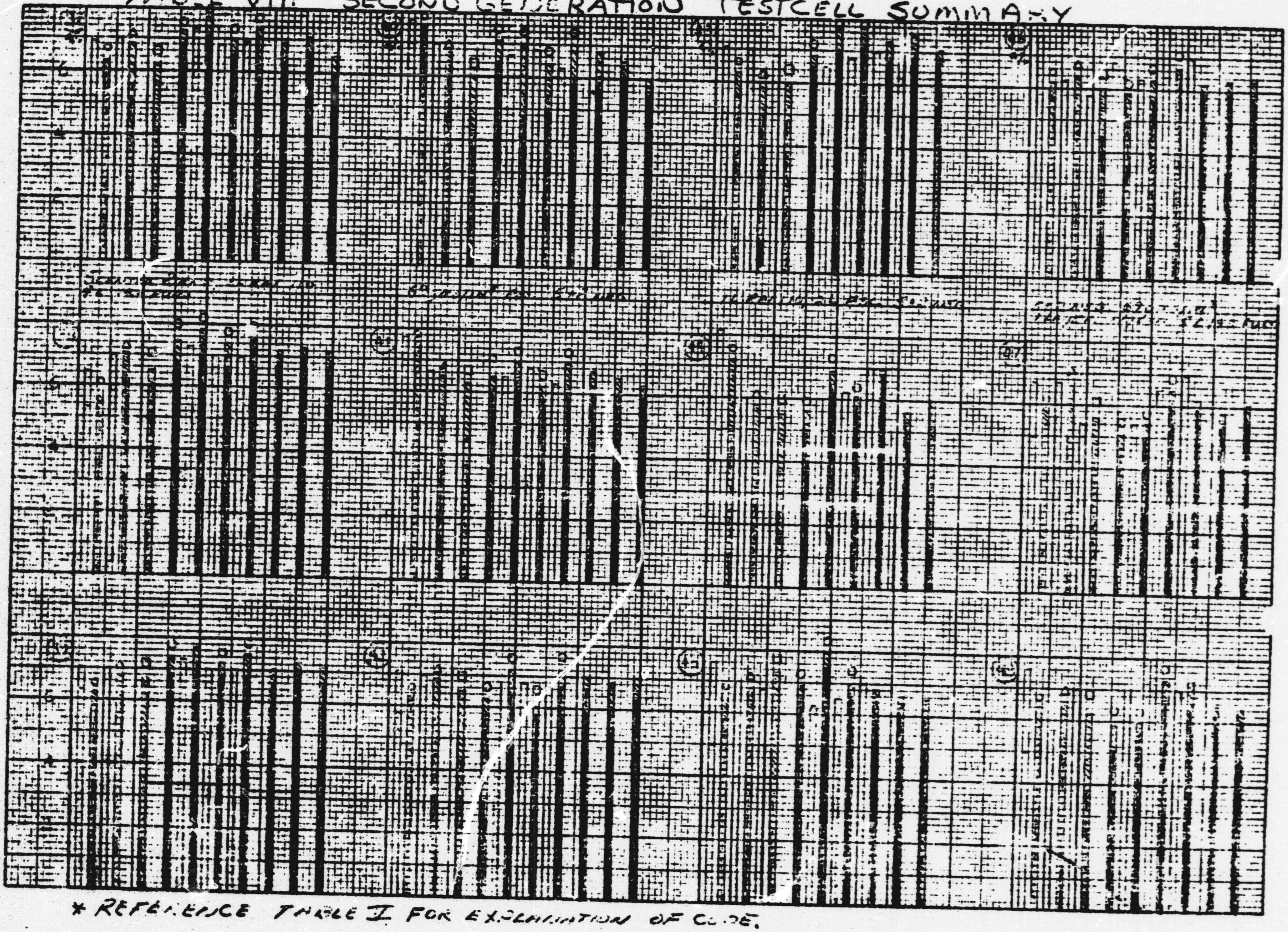
FIGURE 2

DISCHARGE CURVES



KEUFFEL & ESSER CO. 10 X 10 TO THE 1/2 INCH 359-11

TABLE VIII* SECOND GENERATION TESTCELL SUMMARY



* REFERENCE TABLE I FOR EXPLANATION OF CODE.

A cell design was accomplished which would give a plateau voltage of 1.55 volts (1.50 minimum) under a specified load of 500 milliamperes at interrupted periods of operation. A cell jar seal was effected and pressure tests conducted to determine the minimum amount of additive needed to reduce gassing and attack of the electrode grids in a sealed cell design. The design proved capable of charged stand of six months at 90°F and 112 hours at 160°F, delivery of 6.0 ampere hours output and resistant to vibration.

A study was also undertaken to determine bond strength of various materials for the sealed cell jar seal and as a possible seal for the battery canister. The results and calculations were as follows:

$$L \text{ max.} = \frac{yt}{r} \text{ in}$$

L = Lap distance = 0.5

Y = Adherend yield strength, psi

t = Adherent thickness, in

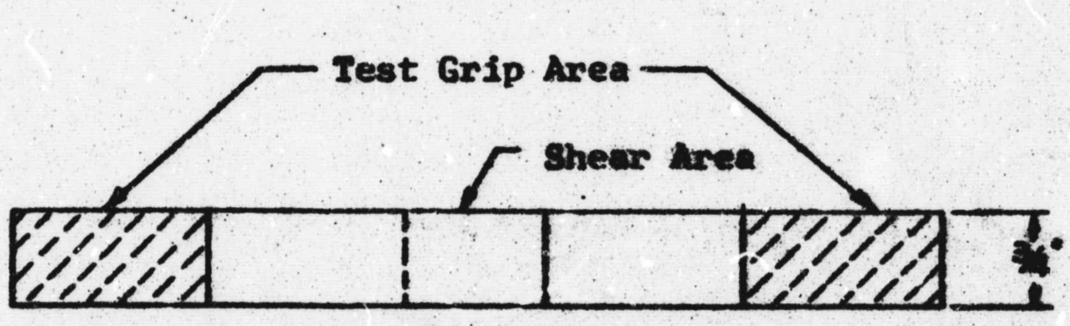
r = 1.5x adhesive shear strength, psi

area of bond = 0.75 wide x 0.5 Lap = 0.375 in^2

$$r = \frac{yt}{L} = 1.5\ (x) = \frac{y \text{ lbs. } (0.003)}{0.5}$$

$$X = \frac{y \text{ lbs. } (0.003)}{0.5\ (1.5)} = \frac{(0.003)\ y}{0.5} = 6 \times 10^{-3}\ y$$

Where y = lbs. force (lbs.)
x = shear strength (psi)



BOND STRENGTH
TEST RESULTS

Bond Description	Pot Life	Test Spec.	Thick-ness Inches	Material Type	Cure Time Hrs.	Force to Break/ lbs.	Break Model	Area Break in^2	Strength (Tensile) lbs/in^2
Epoxy Thickness 828, 24 cc Mfg. 2/3/67	20 min.	1A	0.022	Ti	72	145	Adhesive	0.375	388
		1B	0.010	Ti	Room	160*	Adhesive	0.375	425
		1C	0.020	SS	Temp.	560	Adhesive	0.375	1,490
		1D	0.026	Polystyrene		0	Interface	0.375	0
$\bar{X}$						216		0.375	576
BB-2153	30 min.	2A	0.022	Ti	72	75	Interface	0.375	250
		2B	0.010	Ti	Room	10	Interface	0.375	27
		2C	0.020	SS	Temp.	70	Interface	0.375	186
		2D	0.026	Polystyrene		10	Interface	0.375	27
$\bar{X}$						41		0.375	123
BB-2143D	75 min.	3A	0.022	Ti	72	425	Adhesive	0.375	1,135
		3B	0.010	Ti	Room	115	Interface	0.375	305
		3C	0.020	SS	Temp.	190	Interface	0.375	500
		3D	0.026	Polystyrene		15	Interface	0.375	40
$\bar{X}$						186			495
BB-2101	30 min.	4A	0.022	Ti	72	345	Adhesive	0.375	920
		4B	0.010	Ti	Room	160	Interface	0.375	425
		4C	0.020	SS	Temp.	275	Adhesive	0.375	735
		4D	0.026	Polystyrene		10	Interface	0.375	27
$\bar{X}$						198			527
B-2112	30 min.	5A	0.022	Ti	72	80	Interface	0.375	212
		5B	0.010	Ti	Room	45	Interface	0.375	120
		5C	0.020	SS	Temp.	65	Interface	0.375	173
		5D	0.026	Polystyrene		10	Interface	0.375	27
$\bar{X}$						50			133
BB-2111	2 hrs.	6A	0.022	Ti	72	500	Adhesive	0.375	1,330
		6B	0.010	Ti	Room	50	Adhesive	0.375	133
		6C	0.020	SS	Temp.	120	Interface	0.375	320
		6D	0.026	Polystyrene		15	Material	0.375	40
$\bar{X}$						171			456

Bonding Interface*. Appeared to be slight elastic.
Specimen #3 break mode at material (bonding) interface essentially.

The seal incorporated was tested in a sealed cell with a pressure gage reinstalled in the non-vent hole. The cell was discharged at 0.5 amp for 30 minutes at room ambient with no indication of internal cell pressure. The cell was then put in a chamber at 150°F for 48 hours and then discharged at 0.5 ampere for 30 minutes with an increase of 1.3 psi. Burst pressure of the cell jar is approximately 20 psi. It was concluded that the seal was acceptable. A suitable epoxy seal for the titanium canister was not found. Welding was the method decided upon for the canister seal.

4.2 Thermal Design. - The battery thermal characteristics were estimated using a total emissivity of 0.05 for the canister surface and 0.11 btu-in/hr-ft^2 °F for the insulation. The calculation was first made neglecting the insulation, and the approach then justified by showing that if the surface emissivity is low, the insulation becomes unimportant in delaying the time the battery operated heater must operate and in lowering its operating wattage. The battery was treated as a homogeneous mass, uniform in temperature, suspended in a vacuum chamber with only thermal radiation energy loss or gain. The radiation energy transfer between the battery surface and the surrounding chamber walls is given by:

$$\frac{dQ}{dt} = \frac{\sigma A}{\frac{1}{e} + \frac{A}{w}\left(\frac{1}{ew} - 1\right)} \left(T_W^4 - T^4\right) \quad \text{(eg. 1)}$$

$\frac{dQ}{dt}$ = Net power radiated from the battery surface (watts).

σ = 5.67 x 10^{-8} (MKS units).

A = Battery surface area (sq. m).

A_w = Chamber wall surface area (sq. m)

e = Total emissivity of the battery surface

e_w = Total emissivity of the chamber walls

T = Battery temperature (°K)

T_w = Chamber wall temperature (°K)

t = Time in the chamber

If the chamber walls are black, e_w 1 and equation 1 reduces to:

$$\frac{dQ}{dt} = \sigma eA \left(T_w^4 - T^4\right) \quad \text{(eq. 2)}$$

A small amount of energy radiated is given by:

$$dQ = m\ c\ d\ T \quad \text{(eq. 3)}$$

dT = small change in temperature

m = Battery mass (kg.)

c = Battery specific heat (joules/$_{kg}$-K°)

Combining equations 2 and 3:

$$m\ c\ d\ T = \sigma\ e\ A\ (T_w^{\ 4} - T^4)\ dt \qquad \text{(eq. 4)}$$

$$\int_{T_o}^{T} \frac{dT}{T_w^{\ 4} - T} = \frac{\sigma eA}{mc}\int_{o}^{t} dt$$

Reducing $\dfrac{1}{T_w^{\ 4} - T^4}$ by partial fractions and integrating:

$$\int_{T_o}^{T} \frac{dT}{(T_w^{\ 4} - T^4)} = \frac{1}{4T_w^3}\int_{T_o}^{T} \frac{dT}{T_w - T} + \frac{1}{4T_w^{\ 3}}\int_{T_o}^{T} \frac{dT}{T_w + T} + \frac{1}{2T_w^{\ 2}}\int_{T_o}^{T} \frac{dT}{T_w^{\ 2} + T^2}$$

$$= \frac{1}{4T_w^{\ 3}}\left[\ln \frac{(T_w - T_o)(T_w + T)}{(T_w - T)(T_w + T_o)} + 2 \arctan \frac{(T)}{(T_w)} - 2 \arctan \frac{(T_o)}{(T_w)}\right]$$

$$t = \frac{mc}{4T_w^{\ 3}\sigma\ e\ A}\left[\ln \frac{(T_w - T_o)\ (T_w + T)}{(T_w - T)\ (T_w + T_o)} + 2 \arctan \frac{(T)}{(T_w)} - 2 \arctan \frac{(T_o)}{(T_w)}\right] \qquad \text{(eq. 5)}$$

The specific heat of the battery is estimated by:

$$c = \frac{\sum m_i \times c_i}{m}$$ Summed over all battery parts.

m_i = Mass of each component.

c_i = Specific heat of each component.

m = Battery mass.

Assuming the vacuum chamber walls are the same temperature as the vacuum, battery temperature versus time in the chamber curves for each test cycle are plotted from equation 5 on Figures 3, 4, and 5. The time interval required to change the vacuum temperature at the end of each cycle was neglected. The physical constants of the battery used in drawing the curves were:

$$c = 1075 \text{ joules}/_{kg}\text{-}^\circ K$$

$$m = 0.8 \text{ kg}$$

$$A = 0.0363 \text{ sq. m}$$

$$e = 0.05$$

The minimum permissible battery temperature is 50°F. The thermostat starts the battery heater when the temperature reaches 50°F, and the time the heater must operate is found from Figures 3 and 5. The power radiated from the battery surface at 50°F is found from Figure 6. Combining the power radiated at 50°F with the time the heater must operate, the energy required by the heater to hold the battery at a constant temperature of 50°F is calculated.

Time heater must operate: $\left(15.2 \frac{\text{hrs.}}{\text{cycle}} \times 1 \text{ cycle}\right) + \left(3.5 \frac{\text{hrs.}}{\text{cycle}} \times 6 \text{ cycles}\right) = 36.2 \text{ hrs.}$

Power radiated at 50°F: 0.36 watt

Heater energy: 0.36 watt x 36.2 hrs. = 13 watt-hrs.

Battery capacity needed for heater operation: $\frac{13 \text{ watt-hr.}}{9 \text{ volts}} = 1.45$ amp. hr.

Heater current required: $\frac{1.45 \text{ amp-hr.}}{36.2 \text{ hr.}} = 0.040$ amp.

Resistance required to produce the heat: $\frac{0.36 \text{ watt}}{0.0016 \text{ amp}^2} = 225 \text{ ohms}$

Energy content of battery: 2.2 amp-hr. x 10.8 volts + 2.8 amp-hrs. x 9.3 volts = 49.8 watt-hrs.

Energy available for external power: 49.8 watt-hrs. - 13 watt-hrs. = 36.8 watt-hrs.

The battery is treated as a three part system: (1) the titanium canister, (2) the six-cell unit and (3) the insulation between the cells and canister walls.

For steady heat flow and a uniform temperature gradient, the conduction heat current is given by:

$$\frac{dQ}{dt} = \frac{KA}{L} \Delta T \qquad \text{(eq. 6)}$$

$\frac{dQ}{dt}$ = Power conducted (btu/hr.)

K = Thermal conductivity of the insulation = $\frac{0.11 \text{ btu-in.}}{\text{hr.-sq. ft-F}^\circ}$

t = Time (hr.)

L = Insulation thickness = 0.090 in.

A = Surface area = 0.304 sq. ft.

T = Temperature difference across the insulation (F°)

The heat current per Fahrenheit degree difference across the insulation is calculated assuming the current is perpendicular to the faces of the six-cell unit.

$$\frac{I}{\Delta T} \frac{dQ}{dt} = \frac{(1.1 \times 10^{-1})(3.04 \times 10^{-1})}{(9 \times 10^{-2})} = 0.371 \text{ btu/hr.-F}^\circ$$

$$0.371 \text{ btu/hr.-F}^\circ \times 1055 \text{ joule/btu} \times \frac{1 \text{ hr.}}{3600 \text{ sec.}} = 0.11 \frac{\text{watt}}{\text{F}^\circ} \qquad \text{(eq. 7)}$$

The heat capacity of the six-cell unit = 1260 joules/$_{kg}$-C° x 0.660 kg x $\frac{5C°}{9F°}$ =

$$462 \ \frac{\text{joules}}{F°}$$

The heat capacity of the titanium canister = 586 $\frac{\text{joules}}{\text{kg-C°}}$ x 0.140 kg x $\frac{5C°}{9F°}$ =

$$45.5 \ \frac{\text{joules}}{F°}$$

Before the heater begins to operate:

Net power lost by canister = Power radiated - Power gained by conduction.

Net power lost by six-cell unit = Power lost by conduction.

On the first low temperature cycle, the battery is initially at 80°F throughout. The canister cools continuously, and its rate of cooling depends on the heat capacity and net power lost. Initially, the canister radiates power, and its temperature drops until the temperature difference across the insulation becomes 3 or 4°F. Then from equation 7 and Figure 5, the power lost by the canister and the power gained by conduction becomes comparable, and the net power lost by the canister becomes small compared to the power conducted away from the cells. Since the heat capacity of the cells is large compared to the canister, the cooling rates of the canister and cells become comparable after a time estimated at about an hour. The canister will reach 50°F sooner than in calculation A and the cells reach 50°F later than in calculation A. When the canister is at 50°F, the cells are about 53°F. The cells will cool 3°F in approximately one hour, hence, the time to 50°F will differ from the time found in A by less than one hour.

Heater begins to operate:

When the six-cell unit reaches 50°F, the heater begins to operate, and the cells can be treated as a constant temperature heat reservoir.

Heat will flow to the outside walls until a steady state occurs in which the heat lost by radiation equals the heat gained by conduction. The temperature difference across the insulation in the steady state can be calculated by equating power lost to power gained.

$$\sigma eA \left(T_w^4 - T^4\right) = \frac{KA}{L}\left(T - T_c\right) \qquad \text{(Eq. 8)}$$

$$\sigma eA_1 T^4 + \frac{KA_2}{L} T = \sigma e A_1 T_w^4 + \frac{KA_2}{L} T_c$$

$\sigma = 5.67 \times 10^{-8}$ (MKS)

$e = 0.05$

$A_1 = 0.0363$ sq. m (canister surface area)

$K = 0.0158$ watt-m/sq. m-F°

$A_2 = 0.0282$ sq. m (six-cell unit surface area)

$L = 0.00228$ m

$T_c = 283$°K (cell temperature)

$T_w = 233$°K (chamber wall temperature)

T = canister temperature (°K)

Plugging these constants into equation 8 and trying several values of T, one finds $281 < T < 282$°K. The maximum temperature difference across the insulation is less than 2K° or 3.5F°. Hence, the cells will be at 50°F, and the canister will be approximately 47°F. From Figure 5, the power radiated at 47°F is 0.34 watt. The heater wattage required differs by only 0.02 watt from that used in calculation A. Since the heater wattage and operating time are approximately the same in calculations A and B, the homogeneous battery assumption used in A is justified.

FIGURE 3

BATTERY TEMPERATURE VS TIME IN VACUUM
CHAMBER FOR FIRST 24 HOURS AT -40°F

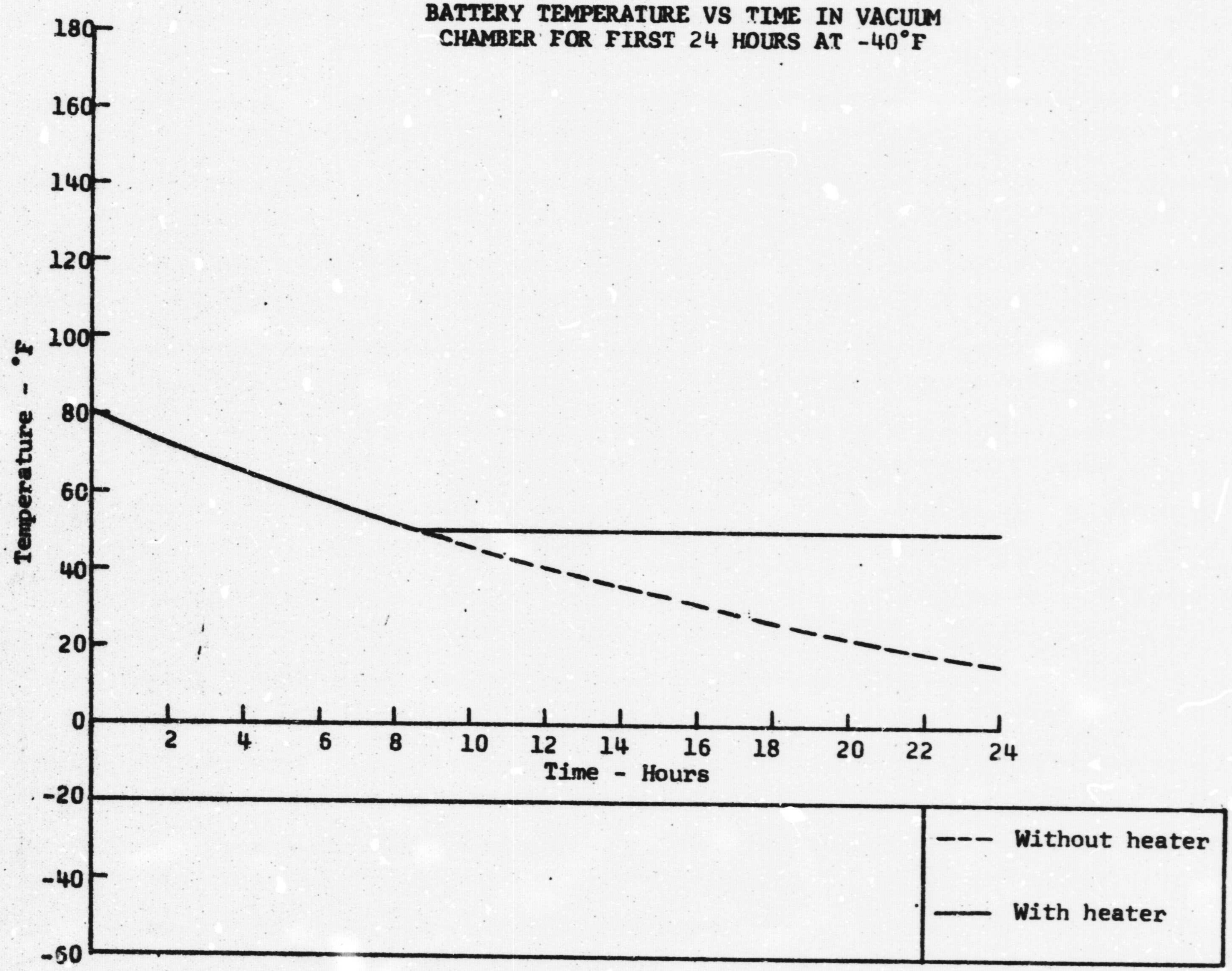


FIGURE 4

BATTERY TEMPERATIRE VS TIME IN VACUUM
FOR EACH OF THE 24 HOUR PERIODS AT 160°F

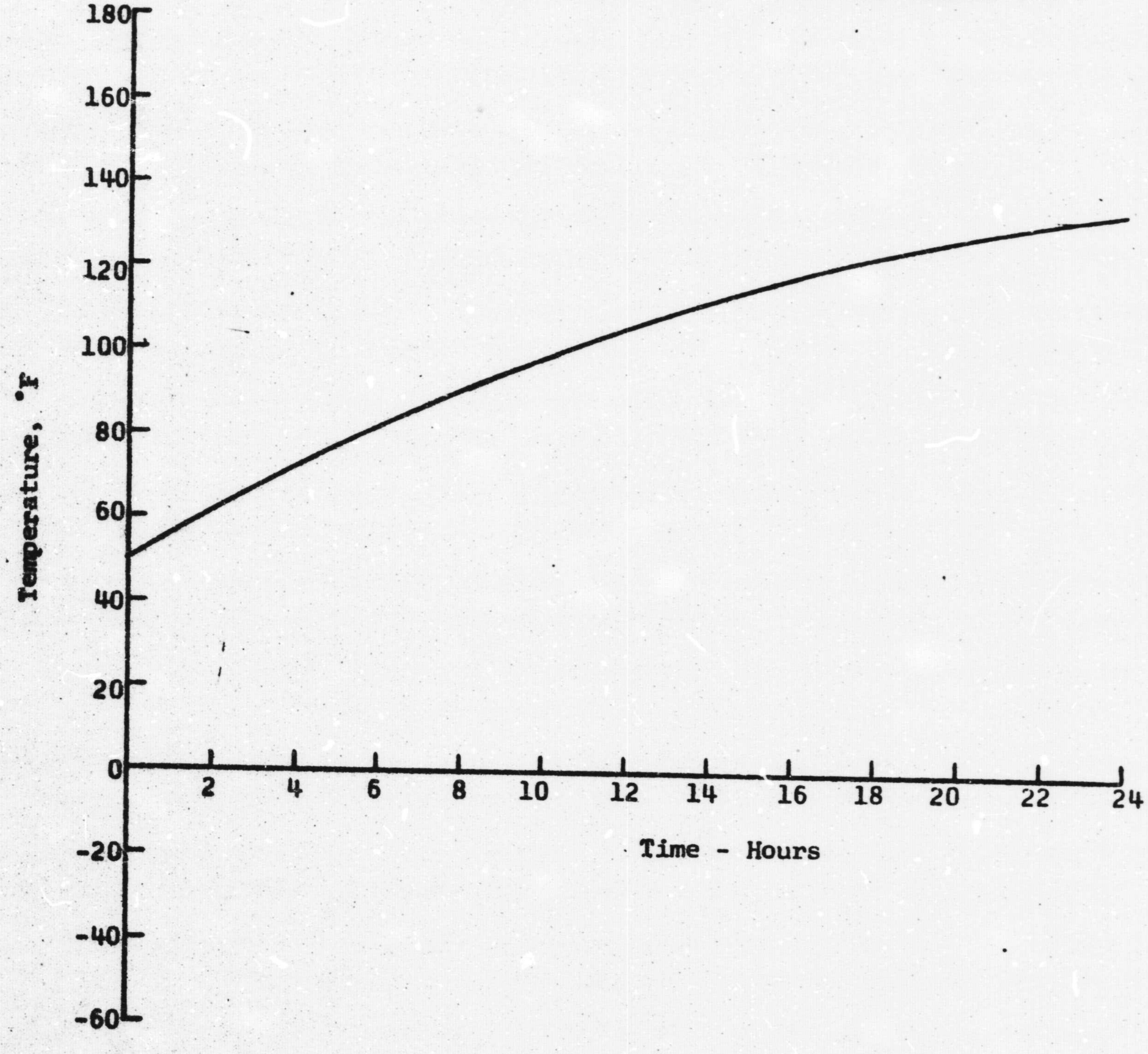


FIGURE 5

BATTERY TEMPERATURE VS TIME IN VACUUM
FOR EACH OF SIX 24 HOUR PERIODS AT -40°F

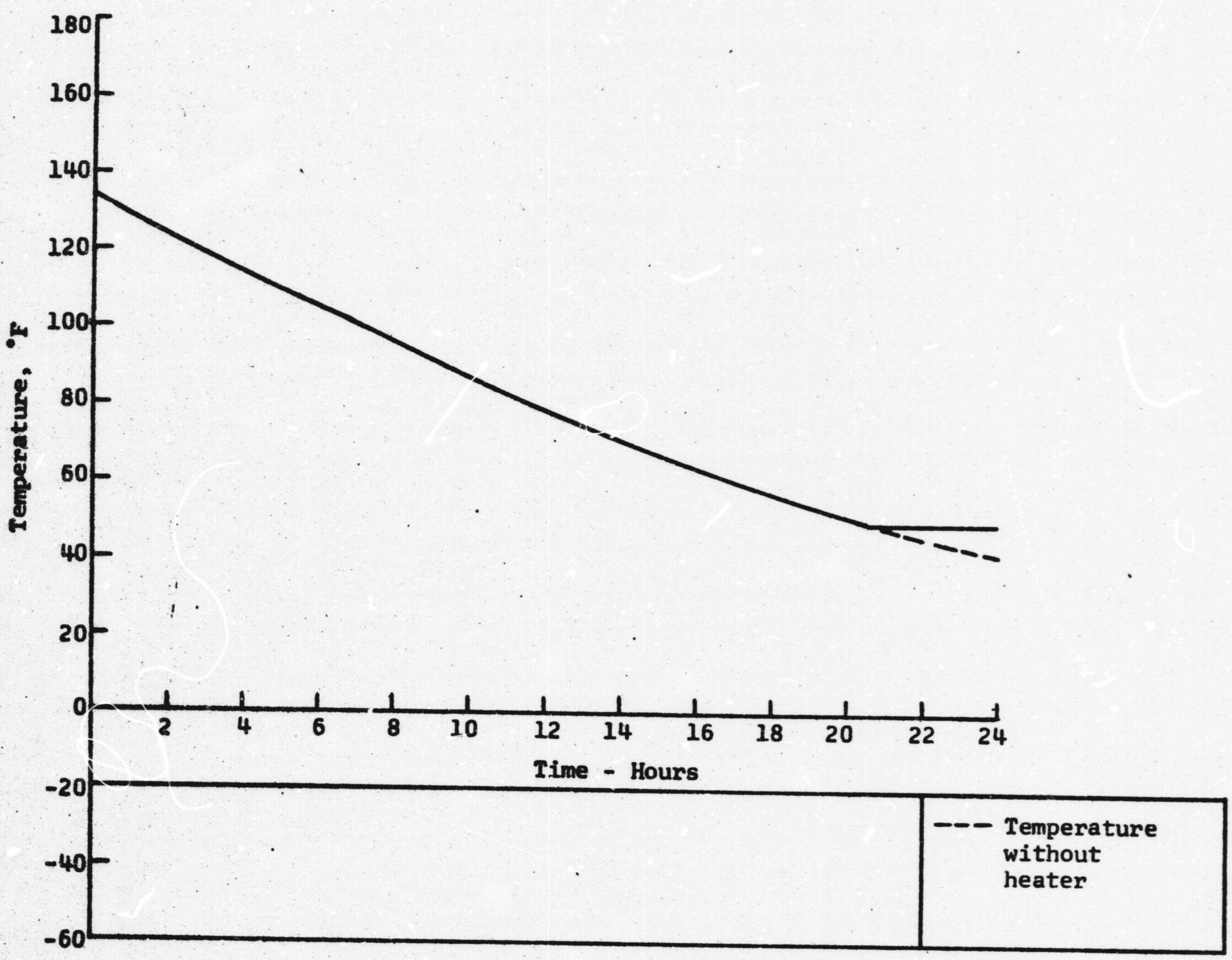
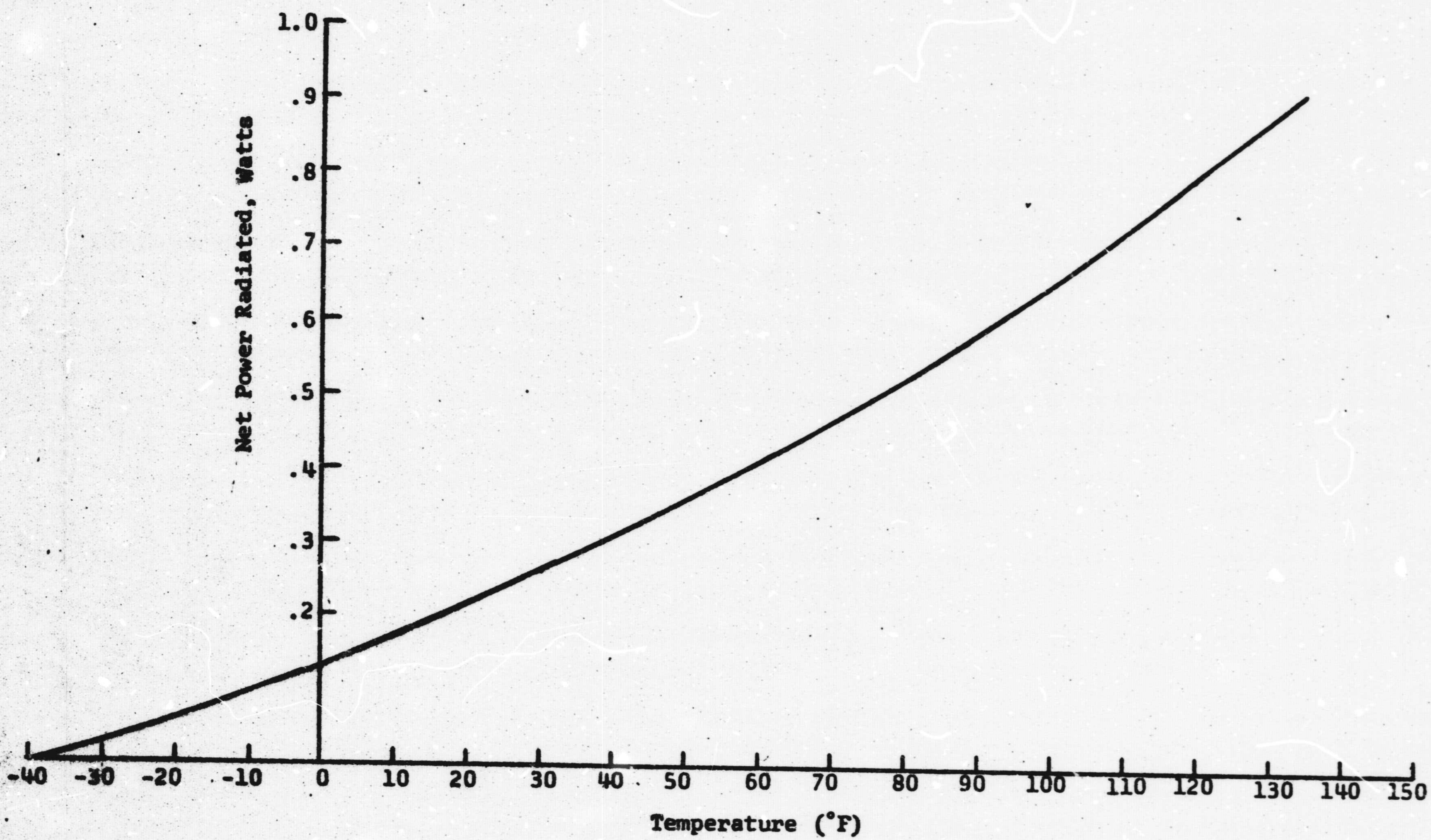


FIGURE 6

NET POWER RADIATED VS BATTERY TEMPERATURE IN VACUUM AT -40°F

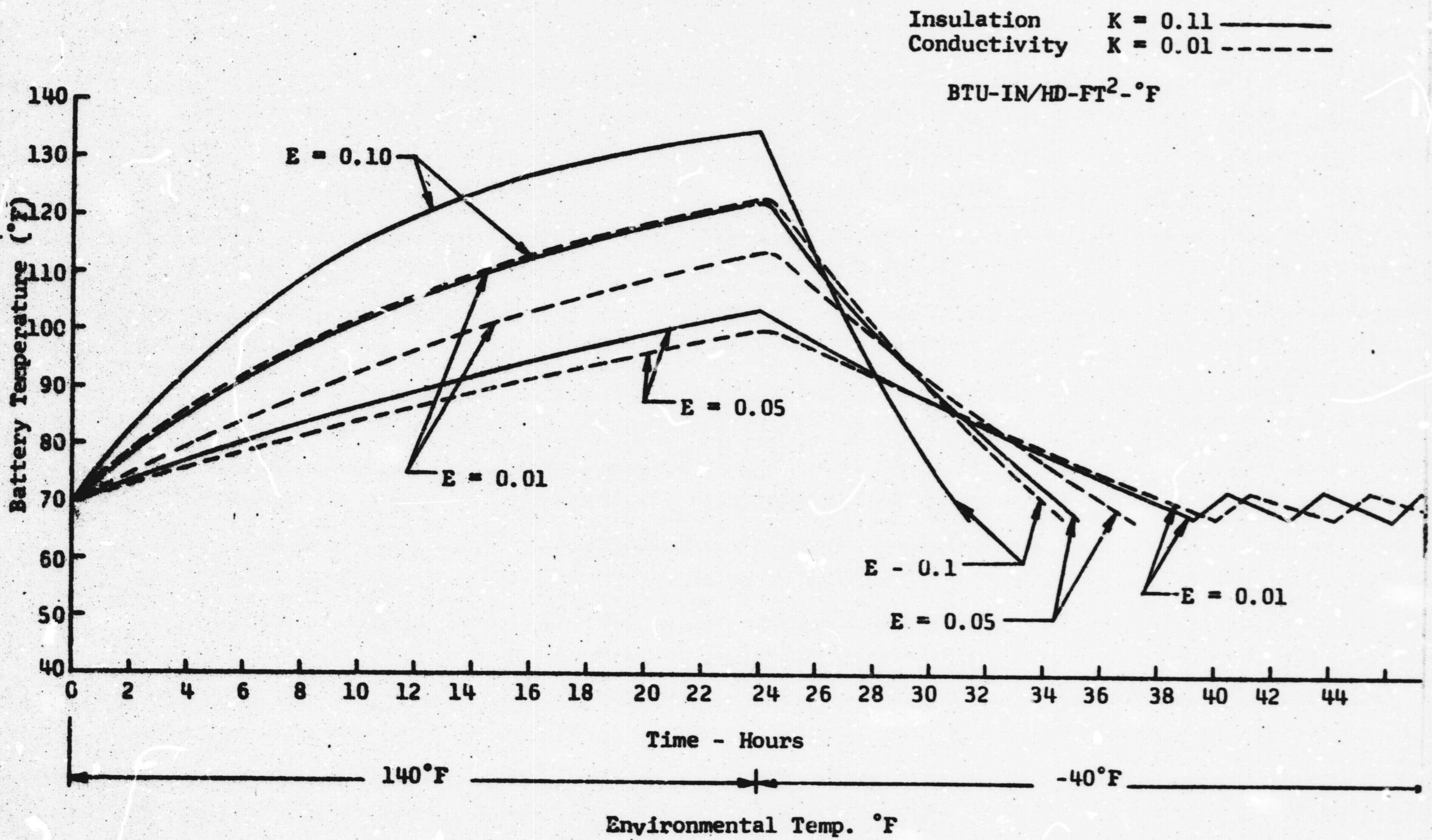


Additional tests and calculations indicated that in order to meet the thermal vacuum requirements, a total emissivity of 0.025 or lower would be required. See Figure 6 for calculated temperature characteristics for various emissivity values. The largest single factor affecting operation during thermal vacuum is the canister emissivity. The titanium battery canister was required to have a lower total emissivity than that which could be obtained by being highly polished. Gold plating the titanium canister was found to result in the best attainable emissivity value. The process for gold plating the final battery assembly was established. The 0.025 or lower value for total emissivity was obtained and verified by tests by NASA/Goddard. The battery was then found to maintain satisfactory thermal control.

Varying types of commercially available insulations were investigated. The final acceptable insulation consisted of multiple layers of mylar and aluminum foil.

FIGURE 7

EMISSIVITY VARIATIONS
VS
HEATER CYCLING



4.3 Thermal Vacuum Test. - Experimental and prototype batteries were manufactured and tested to the thermal vacuum requirements.

The first experimental battery tested to the temperature-altitude requirement was designed such that the heater was manually operated by battery power. When placed in the -40°F environment, from room ambient, the battery heater cut-on temperature of 46°F (inside cell thermocouple measurement) was reached at 7.4 hours. The heater was then again turned on in five hours and discharge was conducted at the 24 hour period. The battery voltage was low (8.9 volts). The ambient was changed to +140°F and after a top-off charge the battery voltage was 9.31 volts which was still considered low. During the 140°F environment, readings were recorded as high as 150°F, other cycles were run but it was found that the low temperature readings were about 20°F too low and the high temperature readings were actually 40°F higher than recorded. It was concluded that the data was incorrect due to chamber controller and recorder data.

A second unit was then tested for a 14-day time duration. The battery was made up of cells that had been on wet storage for approximately 4-5 months with two 60% depth discharge cycles prior to the stand period. Thermocouples were located in the center of the six cell assembly (between cells 3 and 4), at the thermostat sensing point and on the outside of the battery attached to the canister. The battery heater was powered by an external power supply, and only the battery discharges contributed to the capacity delivered from the battery. Capacity delivered during and at the end of the test was 6.5 ampere hours with only 3.5 ampere hours being required by the test (14 discharges at 0.5 amp for 30 minutes). To keep the battery at operating temperature at the -40°F environment approximately 0.8 ampere hours was required per low temperature cycle if the 9.0 VDC minimum voltage was to be met.

From the results of the experimental test batteries, it was decided that the amount of insulation on the end and top of the battery should be increased and that the thermostat should be set at 68°F close, 72°F open as to its location on the heater blanket between the heater and canister. After manufacturing the first prototype battery and starting the temperature-altitude test, it was discovered that the thermostat would not switch off. It was theorized that the thermostat mass was affected by the -40°F environment and was therefore not opening. Tests were then run to determine optimum location of the thermostat and type of thermostat. The battery was suspended by a nylon cord and located in the center of the chamber.

To keep the battery at operating temperature at the -40°F, 1×10^{-6} TORR environment approximately 0.8 ampere-hour was required for the first low temperature cycle. Less capacity was required on subsequent cycles and if the maximum temperature is raised to 160°F, a shorter period of heater warm up would be realized.

The prototype battery was then revised to incorporate more insulation in the area of the thermostat and the thermostat located between the heater blanket and the cells. A revised prototype unit was then tested which had a thermocouple located between the heater blanket and cells and was used to dictate the on-off switching of the power supply.

During these tests, some useful data was gained. It seems that approximately 1.1 watts were required to keep the thermostat cycling and at the same time maintain the battery temperature at such a point that the voltage will not fall below 9.0 volts while being discharged at 0.5 amp. The problem was that on the first -40°F temperature cycle, the battery voltage is approximately 10.2 volts while the heater is operating, but after this cycle and the half hour discharge, the battery voltage while operating the heater is approximately 9.6 volts. The product of this voltage and the current drawn by the heater is less than 1.1 watts and the thermostat does not cycle but stays on the complete time at -40°F. The thermostat is set with a 4 degree differential. When the heater stays on, the time is approximately 16 hours at 0.8 ampere, thus 1.28 AH per cycle or 1.28 x 7 = 8.96 AH to complete the 14 day test. This capacity could not be tolerated.

There were two possibilities to explore to solve the problem:

a. Increase the heater blanket wattage to such a point that 1.1 watts are delivered at 9.4 volts. This would allow the thermostat to cut off and thus conserve capacity.
b. Decrease the battery minimum voltage to 8.6 volts, thus requiring less wattage to insure a battery temperature that will allow operation at the lower voltage.

Two thermal vacuum tests were again conducted on a prototype test battery. The prototype battery had three discharge cycles prior to the first test. The unit had the thermostat located between the battery cells and heater blanket. The data showed that only 3 to 4, 24-hour cycles could be delivered by the battery due to the 30-minute discharge capacities and the heater capacity. It was discovered that during the thermal vacuum test, a shorter period of heater warm up was obtained and the thermostat did cycle for longer periods of time than experienced during prior tests without the thermostat location between the cells and heater blanket. This occurred mainly during the first cycle (room temperature to -40°F) since the battery voltage was high. On subsequent cycles no capacity savings could be realized since the voltage was lower, i.e. wattage lower, and thus the heater was on continuously to maintain the battery at a 55°F environment in order to support the 9.0 volt minimum for battery or 1.50 volts per cell. From the thermal heat calculations, it is evident that the reflectivity of the canister and battery insulation are variables which would affect the predictions by a factor of 2 or 3. Another cause was heat conduction along the leads required for test, i.e. voltage, current, and monitoring leads. It was felt that some of the heat being supplied to the battery by the heater is being conducted through these leads during test, which in turn caused the heater to activate sooner and for longer intervals. A load simulator operated by relays was then manufactured and kept inside the vacuum chamber during all subsequent tests in an effort to reduce heat loss through connections.

Another battery was manufactured incorporating the latest designs and gold plating.

This battery then underwent thermal vacuum test. During the eighth day ofthe fourteen day test, the battery voltage fell below 9.0 volts while discharging under the heater load during the cold temperature cycle. The battery was then recharged while in the vacuum chamber (temperature approximately 75°F). It accepted 6.8 ampere hours to 12.2 volts. A twelve hour cycling test was started, but the unit fell below voltage minimum three days later. Post-mortem of the unit showed that four of six cells had cracked jars which was attributed to excessive gassing during charge to the 12.2 voltage cutoff.

The following test procedure was utilized for the 14 day - 24 hour cycle thermal vacuum test:

a) Remove battery from its protective container and suspend in chamber with nylon lacing so as to insure no contact with chamber wall or load. Hook up battery to load. Insure that the load does not come into contact with the chamber or the battery, and that no wires from the battery are in contact with those from the load.

b) Connect the test equipment to the battery. Install a continuous recorder monitoring battery heater current or voltage so as to tell actual time and an indication of heater on-off characteristics. Install continuous time clock for duration of test.

c) Subject the battery to the following thermal vacuum environment cycling:

1. Stabilize battery in chamber at 1×10^{-6} TORR at 80-90°F for 3 hours.
2. Set chamber temperature at 10°F at the end of the 3rd hour.
3. Set chamber temperature at -20°F at the end of the 4th hour.
4. Set chamber temperature at -40°F at the end of the 5th hour.

This test consists of maintaining the battery in the test chamber at 1×10^{-6} TORR vacuum maximum and cycling the chamber temperature between -40, (+5 -0°F) and +160°F (+0 -5°F) making the change from the high temperature at 24 ±0.5 hour and from the low temperature at 24 ±0.5 hour.

When making changes from the high temperature, do so in three steps. Start change from +160 to +75-80°F, at end of first hour change from +75 to +25-30°F, at end of second hour change from +25°F to -20-25°F, and at the end of the 2-1/2 hour change to -40°F.

When making changes from low temperature to high temperature go from -40°F to +60°F, the 24.0 hour period; from 0°F to +110°F at the end of the first hour; and from +110°F to +160°F at the end of the second hour.

Cycling shall continue for 14 days. Record battery voltage at 5 ±1 hour intervals and chamber-temperature and pressure at one hour intervals (minimum) on data sheet. Keep continuous recording of heater operation.

d) One hour before each temperature change, perform the following procedures:

   1. Set load resistor so that the current drawn is as close to 0.5 amp as can be obtained (either high or low load switch).

   2. Set the load switch to ON for 30± minutes. Record discharge voltage and current each 30 seconds to 3 minutes and each minute to 10 minutes and each 5 minutes to 30 minutes total. Record chamber pressure and temperature at start and 10 minute intervals. The discharge on the 14th day shall be continued until the battery voltage reaches 8.0 volts.

e) Return the chamber pressure and temperature to laboratory ambient.

The step change in temperature was to alleviate possible damage to the test chamber by reducing condensation, etc. The temperature changes were made within three hours maximum. A copy of the data is included as Appendix A of this report. Although heater current readings were not made, the heater capacity was calculated from the known resistance, time and voltage. Heating from room ambient to -40°F consumed approximately 0.96 AH of battery capacity. Each additional high temperature to low temperature cycle consumed approximately 0.65 AH. During the eight days (4 cycles x 0.65 AH) this would equal 2.6 AH. The first low temperature cycle would add .96 AH and the eight discharges (30 min. x 0.5A x 8) 2 AH. Therefore the total capacity delivered by the battery was calculated as 5.56 AH to 9.0 volts or 1.5 volts per cell.

The heater cycled as expected during all the low temperature tests. The indicator temperature is the environment temperature. The abrupt drop in voltage would be as expected for the silver-zinc system under a low current drain in an end of capacity situation.

The inability of the battery to meet 14 days of thermal vacuum was again because of capacity loss caused by heater usage of usable battery discharge capacity. The specification requirement of 4.0 AH could surely be met as demonstrated, but not when a portion of the capacity is delivered to the heater to maintain the battery at operating temperatures at -40°F.

The battery accepted charge while in the vacuum chamber at room ambient. There was a test error in that the cutoff voltage was established at 12.2 volts total or 2.03 volts per cell. Gassing occurred after 1.95 volts per cell or 11.7 total volts which should have been the established cutoff voltage. The subsequent post-mortem of the battery showed that 4 of 6 cells had cracks along the cell jar walls. The cell jar to cover seal was not damaged, nor were the cells shorted. The four cells had leaked electrolyte and there was a direct electrical path to the battery canister.

In spite of this phenomenon, there was no catastorphic failure of the battery during the three days in the vacuum chamber at both temperature extremes after the leakage. There was also no evidence of KOH leakage outside the battery canister, or thermal degradation of any components.

Tests on the gold plating emmissivity of this battery canister gave a value of .03.

After charge, the battery underwent the following test procedures for 12 hour cycling.

a) Subject the battery to the following thermal vacuum environment cycling:

1. Stabilize battery in chamber at 1×10^{-6} TORR at 80-90°F for 2 hours.
2. Set chamber temperature at 10°F at the end of the 2nd hour.
3. Set chamber temperature at -20°F at the end of the 3rd hour.
4. Set chamber temperature at -40°F at the end of the 4th hour.

This test consists of maintaining the battery in the test chamber at 1×10^{-6} TORR vacuum maximum and cycling the chamber temperature between -40, (+5 -0°F) and +160°F (+0, -5°F) making the chamber from the high temperature at 12 ±0.5 hour and from the low temperature at 12 ±0.5 hour.

When making changes from the high temperature, do so in three steps. Start change from +160 to +75-80°F, at end of first hour change from +75 to +25-30°F, at end of second hour change from +25°F to -20-25°F, and at end of the 2-1/2 hour change to -40°F.

When making changes from low temperature to high temperature go from -40°F to +60°F, the 12 hour period; from 0°F to +110°F at the end of the first hour, and from +110°F to +160°F at the end of the second hour.

Cycling shall continue for 14 days. Record battery voltage at 5 +1 hour intervals and chamber-temperature and pressure at 1 hour intervals (minimum) on data sheets. Keep continuous recording of heater operation.

b) One-half hour before each temperature change, perform the following procedures:

1. Set load resistor so that the current drawn is as close to 0.5 amp as can be obtained (either high or low load switch).
2. Set the load switch to ON for 15 minutes. Record discharge voltage and current each 30 seconds to 3 minutes and each minute to 15 minutes. Record chamber pressure and temperature at start and 5 minute intervals. The discharge on the 14th day shall be continued until the battery voltage reaches 8.0 volts.

This test was conducted to gain information as to whether the unit could withstand 14 days of the environment heater on time on a 12-hour cycle basis; that a 12-hour cycle 14-day test could be met, and that the unit could be charged during a 14-day period and meet the 24-hour cycle 14-day test. The 2:30 a.m. discharge at low temperature on July 2 was missed due to personnel error and the unit remained at this low temperature environment for 24 hours.

The test conducted was the most successful to date. The battery capacity was completely utilized and exceeded the 4.0 ampere-hour requirement. Thermal losses appear to be responsible for the inability to meet the 14-day requirement without recharge. Further reduction of thermal losses appear minimal, with the exception of lowering the total emissivity.

A recharge was then permitted during the 14-day period as long as the minimum capacity was met before recharge. This capacity was the sum total of heater and discharge capacity.

One complete battery was then manufactured and tested to the thermal vacuum test outlined above. This unit successfully passed the 14-day thermal-vacuum requirement (1×10^{-6} TORR at -40°F to +160°F). A charge was incorporated between the seventh and eight discharge.

The thermal vacuum test was conducted according to the following procedures:

a) Remove battery from its protective container and suspend in chamber with nylong lacing so as to insure no contact with chamberwall or load. Hook up battery to load. Insure that the load does not come into contact with the chamber or the battery, and that no wires from the battery are in contact with those from the load.

b) Connect the test equipment to the battery. Install a continuous recorder monitoring battery heater current or voltage so as to tell actual time and an indication of heater on-off characteristics. Install continuous time clock for duration of test.

c) Subject the battery to the following thermal vacuum environment cycling:

   1. Stabilize battery in chamber at 1×10^{-6} TORR at 90°F for 3 hours.
   2. Set chamber temperature 10°F at the end of the 3rd hour.
   3. Set chamber temperature at -20°F at the end of the 4th hour.
   4. Set chamber temperature at -40°F at the end of the 5th hour.

This test consists of maintaining the battery in the test chamber at 1×10^{-6} TORR vacuum maximum and cycling the chamber temperature between -40, (+5 -0°F) and +160°F (+0, -5°F) making the change from the high temperature at 24 +0.5 hour -.00 hour and from the low temperature at 24 -0.5 +.00 hour.

When making changes from the high temperature, do so in three steps. Start change from +160 to +75-80°F, at end of first hour change from +75 to +25-30°F, at end of second hour change from +25°F to -20-25°F, and at end of the 2-1/2 hour change to -40°F.

When making changes from low temperature to high temperature go from -40°F to +60°F, the 23.5 hour period; from 0°F to +110°F at the end of the first hour; and from +110°F to +160°F at the end of the second hour.

Cycling shall continue for 14 days. The 24-hour cycling period shall start at the 5th hour per c4 above. Keep continuous recording of heater operation.

d) At the end of the seventh discharge stabilize the chamber temperature at room ambient at 1 x 10^{-6} TORR. Charge the battery at a constant potential of 11.8 volts until the current decays to 0.03 amp. After charge, continue thermal vacuum cycling.

e) One hour before each temperature change, perform the following procedures:

   1. Set load resistor so that the current drawn is 0.5 amp (either high or low load switch).
   2. Set the load switch to ON for 30± minutes. Record discharge voltage and current each 30 seconds to 3

minutes and each minute to 10 minutes and each 5 minutes to 30 minutes total. Record chamber pressure and temperature at start and 10 minute intervals. The discharge on the 14th day shall be continued until the battery voltage reaches 8.5 volts.

f) Return the chamber pressure and temperature to laboratory ambient.

The data obtained during this test is included as Appendix B to this report.

This unit had the best gold plating obtained to date. Tests at NASA Goddard indicated that the total emissivity was 0.02 to 0.03 depending on the test area of canister.

During the seventh discharge the battery voltage at low temperature was 9.03 volts at the end of discharge. The battery was then put on charge at a constant potential of 11.8 volts with the current decay set at .03 amp. Approximately 6.5 ampere hours was put back into the battery. On the 17th day (14th discharge), the battery ran for 120 minutes to 9.0 volts, and 128.5 minutes to 8.5 volts. This indicated that approximately 2-3 additional days of thermal-vacuum cycling might have been obtained. This test then successfully completed the requirements of the specification with the charge being permissible during the 14-day period.

4.4 Pressure Relief Valve Burst Tests. - There is approximately 14 cc's of 40% KOH in each cell for a total of 84 cc's per battery. The boiling point of 40% KOH at 1 atmosphere is 124°C. The vapor pressure of 40% KOH at 124°C is 14 psi. A relief valve was selected that would relieve at 25 psig maximum and reseat at 15 psig minimum.

A sealed battery canister was filled with 80 cc's of water and brought to a boil. One hour later the boiling was stopped, unit cooled down and pressure checked. There was no evidence of rupture of the canister and the pressure check was acceptable. There was an indication that the relief valve opened 3-4 times during the test. It is considered that the efficiency of the design was demonstrated by this test.

5.0 DESIGN/TECHNICAL AND WEIGHT ANALYSIS

The battery is required to operate in a vacuum of 1 x 10^{-6} TORR after being stabilized for 24 hours each at -40°F and +160°F for seven repeated cycles.

Insulation materials were investigated and tested. The best insulation that was tested was manufactured at ESB which consisted of multiple layers of aluminum foil and mylar. An insulation of this type is not commercially available, and is considered as being better than anything available for the thickness required. A 44°F thermal gradient between the cells and outer canister was obtained with the insulation. The use of this type insulation in a battery and the manufacture of the insulation was an improvement in the state-of-the-art of battery insulation in the thickness range of 0.05 inch.

The weight design goal for the battery was 1.5 pounds, and a specified maximum weight of 2.0 pounds. The accomplished final weight was

1.78 pounds. ESB utilized materials and design parameters to insure minimum weight and maximum strength. The energy density was 33 WH/lb. and 1.94 WH/in^3 which is well in excess of the "state-of-the-art" for small silver-zinc batteries with a cut-off voltage of 1.50 volts per cell (9 volts per battery). Titanium was found to be the best canister material to insure minimum weight and maximum strength. Due to the dimensions and close tolerances, welding of the canister was an important factor. It was considered a major accomplishment to have the final weldment within the required dimensions. See Table IX for canister weldment dimensional data.

TABLE IX

NASA/HOUSTON CANISTER WELDMENT DIMENSIONAL DATA
DRAWING SK-9089

Drawing Requirement	Canister S/N 1	Canister S/N 2	Canister S/N 3
2.560 ± .005	2.564	2.562	2.561
1.00 ± .030	1.000	1.000	1.000
2.81 ± .030	2.802	2.807	2.809
1.39 ± .030	1.391	1.397	1.396
1.570 ± .005	1.567	1.567	1.569
.190 ± .010	.196	.193	.193
.194 ± .010	.193	.193	.191
.562 ± .005	.565	.561	.561
2.940 ± .030	2.915	2.912	2.917
4.60 ± .015	4.585	4.597	4.592
4.75 ± .030	4.755	4.764	4.761
.080 ± .010	.085 .085	.087 .085	.083 [illegible]
.040 Max	.040	.040	.040
.53 ± .030	.540	.541	.543
1.00 ± .030	1.00	1.00	1.00
.2500 ± .0005	.250 .250	.250 .250	.250 .250
.40 ± .030	.408	.402	.403
.40 ± .030	.402	.409	.402
2.25 ± .030	2.245 2.240	2.251 2.450	2.240 2.243
1.990 ± .010	1.987	1.989	1.991
.85 ± .030	.853	.851	.855
.562 + .005 - .000	.565	.560	.563
3.17 ± .030	3.170	3.171	3.167
.700 + .000 - .010	.690	.689	.694
1.810 ± .005	1.780 + 1.824	1.802 + 1.805	1.800 + 1.810

Electron beam welding was used to make the canister to cover seal with the battery cells, insulation, and other parts within 0.1 inch of the welded area. An assembly of this type had not previously been done and was considered a major accomplishment for producing close tolerance welds on thin titanium effecting a canister seal capable of withstanding 1×10^{-9} TORR for 48 hours without leakage.

A Kapton heater blanket only 0.015" thick and capable of insulation resistance of over 1000 megohms was designed to maintain battery operation temperature during -40°F exposure. Also, differential heating capacity at various points in the heater, corresponding to different heat requirements (e.g. end cells) was incorporated.

Cell designs were investigated which would give a plateau voltage of 1.50 volts under the specified load at interrupted periods of operation. Accomplishing the higher plateau and cut-off voltages at interrupted periods of operation is considered and extension of the "state-of-the-art." Normal or standard silver-oxide-zinc systems would have a plateau voltage of 1.40 volts and a cut-off voltage of 1.35 volts. To accomplish the high plateau voltage a cell study was undertaken to study the positive plate densities, electrolyte concentrations, and separators consisting of fibrous sausage casing, cellophane, polypropylene, and irradiated polyethylene. Some of these separators had not previously been utilized in the combination investigated in sealed cells. Another new investigation for sealed cells was the incorporation of positive plate additives of lead oxide and palladium. These additives had not previously been incorporated in the sealed cell design. The study of RAI materials in 31% KOH was to decrease the normal high resistance of the RAI material in order to maintain the 1.50 V/C minimum voltage requirement while insuring the cycle and wet life requirements. The 31% KOH tests also demonstrated the chemical inertness of the RAI material at 160°F in the sealed cell design. The positive plate additives were studied to take full advantage of the energy density of the system. With standard positive electrodes, 65% of theoretical silver capacity was available, but with the lead additives almost 75-80% of the theoretical silver capacity was possible. These additives were not considered in the final design since they were detrimental to the electrode grids and attacked the separators in the sealed cell design whereas they had been found beneficial in previous unsealed approaches. The additive information should be considered as being helpful although they were not incorporated. The Emulphogene BC-840 negative plate surfactant additive to increase cycle life by retarding zinc penetration through the separator system was investigated but found to lower the cell voltage and thus its contribution to cycle life could not be utilized.

Tests were conducted on an ESB/EMED proprietary additive compound to the negative plate in an effort to reduce negative electrode grid erosion and gassing of the negative plate. Large percentages of the compound as used in vented cells reduce gassing but increases erosion of the grid. For the sealed cell design, gassing had to be minimized but long life was required. A lower percentage of the additive was incorporated.

Many tests were conducted, and cell jar to cover seal adhesives investigated to insure a reliable seal at the gassing pressure generated. The battery's useful life was also extended thus insuring a reliable MTBF. The cell design proved to be capable of charged stand of six months at 90°F and 112 hours at 160°F, delivery of 6.0 ampere-hour output, and resistant to the specified requirements. The overall cell design is considered by ESB as being an advancement of the state-of-the-art for a sealed cell approach.

The final battery design consisted of:

- Six cells - silver-oxide-zinc - sealed construction
- Titantium canister - sealed - electron beam welded - gold plated - emissivity of .025
- Self-operating at temperatures from -40°F with thermostatically controlled Kapton heater blanket
- Aluminum foil and mylar insulation
- Sealed electrical connector
- Pressure relief valve

The deliverable battery had the following characteristics, which were observed during final acceptance tests.

TEST PROCEDURE TITLE
ACCEPTANCE TEST PROCEDURE FOR MODEL 347 BATTERY

MODEL NUMBER	PART NUMBER	SERIAL NUMBER	INSPECTOR	DATE
347	347-1000	1	17	1-30-70

Q. C. SUPERVISION	DATE	CUSTOMER	DATE
W. Clayton Rodgers	1-30-70	NASA 889	1-30-70

REMARKS

ACCEPT: Inspector 17
REJECT: ____________

REFERENCE PARAGRAPH	ATTRIBUTE	REQUIREMENT	ACTUAL
6.3	Preparatory Procedure	Read	Inspector 17
6.4	Calibration	Within Calibration Period	Inspector 17
7.1	Visual	Acceptable	Inspector 17
7.2	Ident. & Marking	Acceptable	Inspector 17
7.3	Weight	2.0 lbs. Max.	1.78
7.4 A.	Dimension	2.25 ± .03 (Inches)	2.258, 2.248
B.	Dimension	1.990 ± .010 (Inches)	2.002
C.	Dimension	0.2500 ± 0.0008 (Inches)	0.2507, 0.2504
D.	Dimension	4.76 ± .03 (Inches)	4.775
E.	Dimension	4.600 ± 0.015 (Inches)	4.608
F.	Dimension	0.040 Max. (Inches)	0.039
G.	Dimension	0.7 Max. (Inches)	0.360
H.	Dimension	2.560 ± 0.005 (Inches)	2.5656
J.	Dimension	1.39 ± 0.03 (Inches)	1.397, 1.392
K.	Dimension	2.81 ± 0.03 (Inches)	2.800
L.	Dimension	3.17 ± 0.03 (Inches)	3.150
M.	Dimension	1.810 ± 0.005 (Inches)	1.825, 1.844
N.	Dimension	0.700 +0.000 -0.010 (Inches)	0.675, 0.685
8.1.5	Weight Loss	25 Milligrams Max.	$.03 \times 10^{-6}$
8.2.5 A.	Insulation Resistance	500 Megohms Min.	4K Megohms
B.	Insulation Resistance	500 Megohms Min.	4K "
C.	Insulation Resistance	500 Megohms Min.	4K "
8.3.3	Battery Temperature	(To be determined)	66°F
8.3.5	Battery Temperature	(To be determined)	72°F
8.4.3	Battery Voltage	11.0 Volts Min.	11.06

6.0 ENGINEERING LIAISON

On August 24, 1967, a meeting was held at EMED Raleigh to discuss engineering aspects of the contract. Mr. J. B. Trout of NASA and Messrs. W. D. Bulla, Jr and D. B. Colbeck of EMED discussed various areas of the battery design and the design of second generation test cells.

At this meeting it was decided that:

- Cut down chassis size in section not being used for cells to reduce weight and volume.
- The mating connector to the battery will be shunted so that when not mated with the battery, the heater system will be deactivated.
- Cell interchangeability waived to allow a more reliable, lower weight canister seal.

It was also decided to delete the requirements of testing for salt spray and humidity, and adding a method of controlled pressure relief of the canister.

NASA Technical Monitor, Cliff Robinson met at ESB to discuss the thermal study conducted by NASA as decided in an engineering and contracts meeting at NASA/Houston on January 16 and 17, 1969.

APPENDIX A

TEST DATA

EXIDE MISSILE & ELECTRONICS DIVISION — ESB INCORPORATED	Exide	TEST DATA SHEET	T. W. O. NO. 69-056
TEMPERATURE -40°F to +160°F	SPEC. NO. NASA EXHIBIT "A"		J.O. NO. 84068
CURRENT 0.5 amp	ITEM TESTED Model 457		SERIAL NO. X3
OUT VOLTAGE 9.0 Volts	PROJ. ENG. W.D. Bulla, Jr.		DATE 6-18-69

Discharge	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11
Date	6-21	6-22	6-23	6-24	6-25	6-26	6-27	6-28			
Clock Time	9:00	9:00	9:00	9:00	9:00	9:00	9:00	9:00			
Load (ohms)	18.22	18.34	18.22	18.34	18.22	18.34	18.22	18.34			
Chamber Temp. Start	-40°F	155°F	-35°F	157°F	-35°F	155°F	-35°F	155°F			
10 min.	-40°F	155°F	-35°F	157°F	-35°F	155°F	-35°F	155°F			
20 min.	-40°F	155°F	-35°F	157°F	-35°F	155°F	-35°F	155°F			
30 min.	-40°F	155°F	-35°F	157°F	-35°F	155°F	-35°F	155°F			
Chamber Pressure Start	6.2×10^{-6}	2.7×10^{-5}	4.4×10^{-6}	2.0×10^{-5}	8.2×10^{-6}	1.0×10^{-5}	6.1×10^{-6}	2.1×10^{-5}			
10 Min. (TORR)	9.3×10^{-6}	1.4×10^{-5}	4.0×10^{-6}	1.6×10^{-5}	4.7×10^{-6}	1.9×10^{-5}	8.5×10^{-6}	1.4×10^{-5}			
20 Min. (TORR)	6.4×10^{-6}	1.4×10^{-5}	8.2×10^{-6}	2.3×10^{-5}	4.2×10^{-6}	2.6×10^{-5}	4.1×10^{-6}	1.1×10^{-5}			
30 Min. (TORR)	7.2×10^{-6}	1.4×10^{-5}	4.2×10^{-6}	2.5×10^{-5}	4.9×10^{-6}	1.9×10^{-5}	4.4×10^{-6}	1.4×10^{-5}			
Timer Time	on 0	on 0	on 0	on 0	on 0	on [illegible]	on 0	on 0			
0.5 min.	9.25	9.41	9.18	9.43	9.10	[illegible]	9.0	9.38			
1.0	9.27	9.40	9.20	9.42	9.18	[illegible]	9.03	9.35			
1.5	9.23	9.40	9.18	9.41	9.14	[illegible]	9.05	9.33			
2.0	9.22	9.40	9.18	9.40	9.19	9.40	9.10	9.32			
2.5	9.22	9.40	9.20	9.40	9.15	9.40	9.06	9.31			
3.0	9.27	9.40	9.20	9.39	9.20	9.39	9.02	9.30			
4.0	9.26	9.40	9.19	9.39	9.15	9.38	9.01	9.30			
5.0	9.20	9.40	9.20	9.38	9.20	9.37	9.02	9.29			
6.0	9.23	9.39	9.21	9.37	9.15	9.36	9.02	9.28			
[illegible]	9.22	9.38	9.21	9.36	9.15	9.34	9.10	9.28			
8.0	9.22	9.38	9.21	9.35	9.19	9.33	9.10	9.27			
9.0	9.20	9.38	9.21	9.35	9.13	9.33	9.10	9.26			
10.0	9.15	9.38	9.19	9.35	9.18	9.32	9.05	9.25			
15.0	9.20	9.37	9.20	9.35	9.17	9.31	9.09	9.23			
20.0	9.15	9.35	9.20	9.33	9.17	9.31	9.07	9.21			
25.0	9.19	9.35	9.20	9.32	9.17	9.30	9.05	9.20			
30.0	9.18	9.35	9.20	9.32	9.16	9.30	9.05	9.19			
Timer Time	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0			
TIME TO OUT VOLTAGE	X	X	X	X	X	X	X	X			
CAPACITY TO OUT VOLTAGE	X	X	X	X	X	X	X	X			

PREPARED BY /S/ Phil Woodcock

EXIDE MISSILE & ELECTRONICS DIVISION ESB INCORPORATED	Exide TEST DATA SHEET	T. W. O. NO 69-056
TEMPERATURE -40°F to 160°F	SPEC. NO. NASA EXHIBIT "A"	J. O. NO. 84068
CURRENT 0.5 amps	ITEM TESTED Model 347	SERIAL NO. X3
OUT VOLTAGE 9.0 Volts	PROJ. ENG. W. D. Bulla, Jr.	DATE 6-20-69

Time	Battery Volts		Pressure (TORR)		Indicator Temp.		Recorder Temp.		Heater On	Heater Off	
0800	11.12				+10°F						
0900	11.12				-20°F						
1000	11.12		1.6×10^{-5}		-40°F						
1100	11.12		2.2×10^{-5}		-35°F						
1200	11.12		2×10^{-5}		-35°F						
1300	11.12		2×10^{-5}		-35°F						
1400	11.12		2×10^{-5}		-35°F				Heater operating approx. on time .5 sec.		
1500	10.6		2×10^{-5}		-35°F			Heater Cycling	2 sec.		
1600	10.1		2×10^{-5}		-35°F			"	4 sec.		
1700	10.0		2.4×10^{-5}		-35°F			"	2 sec.		
1800	10.0		2.1×10^{-5}		-35°F			"	1 sec.		
1900	9.8		2.5×10^{-5}		-35°F			"	1 sec.		
2000	9.8		2.9×10^{-5}		-35°F			"	3 sec.		
2100	9.8		2.6×10^{-5}		-35°F			"	4 sec.		
2200	9.75		2.6×10^{-5}		-35°F			"	6 sec.		
2300	9.75		2.8×10^{-5}		-35°F			"	25 sec.		
0000 6-21	9.80		2.5×10^{-5}		-35°F			"	.10sec.		
0100	9.60		1.6×10^{-5}		-35°F			"	.10sec.		
0200	9.60		3.8×10^{-6}		-35°F			"	.10sec.		
0300	9.60		3.8×10^{-6}		-35°F			"	.10sec.		
0400	9.60		3.8×10^{-6}		-35°F			"	.10sec.		
0500	9.60		3.8×10^{-6}		-35°F			"	.10sec.		
0600	9.60		3.8×10^{-6}		-35°F			"	.10sec.		
0700	9.55		3.8×10^{-6}		-35°F			"	.10sec.		
0800	9.55		4.6×10^{-6}		-35°F			"	30sec.		
0900	9.55		5.2×10^{-6}		-35°F			Heater cycling every few sec.			
1000	9.70		5.2×10^{-6}		-35°F changes to 60°			Cycling continuously			
1100	9.78		7.4×10^{-6}		60°F changed to 110°			Cycling continuously			
1200	9.80		9.0×10^{-6}		110°F changed to 155			Heater off			
1300	9.80		no read		155°F			"			
TIME TO OUT VOLTAGE											
CAPACITY TO OUT VOLTAGE											

PREPARED BY /S/ Phil Woodcock

FORM NO. [illegible]

EXIDE MISSILE & ELECTRONICS DIVISION — ESB INCORPORATED — Exide	TEST DATA SHEET	T. W.O. NO. 69-056
TEMPERATURE -40°F to 160°F	SPEC. NO. NASA EXHIBIT "A"	J.O. NO. 84068
CURRENT 0.5 amps	ITEM TESTED Model 347	SERIAL NO. X3
OUT VOLTAGE 9.0 Volts	PROJ. ENG. W. D. Bulla, Jr.	DATE 6-21-69

Time	Battery Voltage		Pressure (TORR)		Indicator Temp.				Heater On	Heater Off	
1400	9.80		.6x10^{-5}		155°F				off high temp.		
1500	9.60		.8x10^{-5}		155°F				"		
1600	9.60		1.6x10^{-5}		155°F				"		
1700	9.60		1.2x10^{-5}		155°F				"		
1800	9.60		1.4x10^{-5}		155°F				"		
1900	9.60		1.4x10^{-5}		155°F				"		
2000	9.60		1.2x10^{-5}		155°F				"		
2100	9.60		0.4x10^{-5}		155°F				"		
2200	9.60		0.2x10^{-5}		155°F				"		
2300	9.60		0.2x10^{-5}		155°F				"		
2400	9.60		0.1x10^{-5}		155°F				"		
0100	9.60		0x10^{-5}		155°F				"		
0200	9.60		0x10^{-5}		155°F				"		
0300	9.80		2.6x10^{-5}		155°F				"		
0400	9.80		2.10^{-5}		155°F				"		
0500	9.80		3x10^{-5}		155°F				"		
0600	9.82		3x10^{-5}		155°F				"		
0700	9.82		2.6x10^{-5}		155°F				"		
0800	9.82		2.6x10^{-5}		155°F				"		
0900	9.82		2.7x10^{-5}		155°F				"		
1000	9.58		1.[illegible]x10^{-5}		60°F changed				"		
1100	9.59		1.6x10^{-5}		60°F changed to 25°				"		
1200	9.59		1.5x10^{-5}		25°F changed to -35°F				"		
1300	9.59		1.0x10^{-5}		-35°F						
1400	9.60		0x10^{-5}		-35°F			heater cycling	on 2 sec.	off 5 min.	
1500	9.60		0x10^{-5}		-35°F			"	"	"	
1600	9.60		0x10^{-5}		-35°F			heater off			
1700	9.60		0x10^{-5}		-35°F			"			
1800	9.60		0x10^{-5}		-35°F			"			
1900	9.60		0x10^{-5}		-35°F			"			
TIME TO OUT VOLTAGE											
CAPACITY TO OUT VOLTAGE											

PREPARED BY /S/ Phil Woodcock

EXIDE MISSILE & ELECTRONICS DIVISION ESB INCORPORATED	Exide	TEST DATA SHEET	T. W.O. NO 69-056
TEMPERATURE -40°F to 160°F	SPEC. NO. NASA EXHIBIT "A"		J.O. NO. 84068
CURRENT 0.5 amps	ITEM TESTED Model 347		SERIAL NO. X3
OUT VOLTAGE 9.0 Volts	PROJ. ENG. W. D. Bulla, Jr.		DATE 6-22-69

Time	Battery Voltage		Pressure (TORR)		Indicator Temp.				Heater On	Heater Off	
2000	9.60		9×10^{-5}		-35°F						
2100	9.60		8×10^{-6}		-35°F						
2200	9.52		7.6×10^{-6}		-35°F			possible cycling between 9.45 & 9.55 = 10 sec. on time			
2300	9.50		8.4×10^{-6}		-35°F			cycling on time=10 sec.			
0000	9.50		7.4×10^{-6}		-35°F			cycling on time=10 sec.			
0100 (6/23/69)	9.50		8.6×10^{-6}		-35°F			cycling on time=12 sec.			
0200	9.50		8.3×10^{-6}		-35°F			cycling on time=10 sec.			
0300	9.50		8.4×10^{-6}		-35°F			cycling on time= 5 sec.			
0400	9.50		8.7×10^{-6}		-35°F			cycling on time= 8 sec.			
0500	9.50		8.7×10^{-6}		-35°F			heater off	5 sec.	5 sec.	
0600	9.50		8.9×10^{-6}		-35°F			heater off	8 sec.	4 sec.	
0700	9.50		8.8×10^{-6}		-35°F			heater off	10 sec.	5 sec.	
0800	9.49		4.2×10^{-6}		-35°F			heater off	10 sec.	4 sec.	
0900	9.40		4.4×10^{-6}		-35°F				cycling		
		changed temperature to +60° @ 26.5 hrs. after discharge									
1000	9.52		4.6×10^{-6}		+60°F				heaters off		
1100	9.59		4.1×10^{-6}		+110°F				heaters off		
1145	9.59		1×10^{-6}		155°F	change			heaters off		
1200	9.59		8.8×10^{-6}		155°F				heaters off		
1313	9.60		6.2×10^{-6}		155°F				heaters off		
1410	9.60		6.2×10^{-6}		155°F				heaters off		
1515	9.60		6.7×10^{-6}		155°F				heaters off		
1600	9.575		7.3×10^{-6}		155°F				heaters off		
1715	9.50		7.3×10^{-6}		155°F				heaters off		
1800	9.575		7.6×10^{-6}		155°F				heaters off		
1900	9.575		7.2×10^{-6}		155°F				heaters off		
2000	9.575		7.6×10^{-6}		155°F				heaters off		
2100	9.575		7.6×10^{-6}		155°F				heaters off		
2200	9.50		8.6×10^{-6}		155°F				heaters off		
2300	9.575		9.4×10^{-6}		155°F				heaters off		
TIME TO OUT VOLTAGE											
CAPACITY TO OUT VOLTAGE											

PREPARED BY /S/ Phil Woodcock

EXIDE MISSILE & ELECTRONICS DIVISION — ESB INCORPORATED	Exide	TEST DATA SHEET	T. W.O. NO. 69-056
TEMPERATURE -40°F to 160°F	SPEC. NO. NASA EXHIBIT "A"		J.O. NO. 84068
CURRENT 0.5 amps	ITEM TESTED Model 347		SERIAL NO. X3
OUT VOLTAGE 9.0 Volts	PROJ. ENG. W. D. Bulla, Jr.		DATE 6-22-69

Time	Battery Voltage		Pressure (TORR)		Indicator Temp.				Heater On	Off	
2400	9.50		9.6×10^{-6}		155°F					heaters off	
0100	9.55		9.1×10^{-6}		155°F					"	
0200	9.55		6.3×10^{-6}		155°F					"	
0300	9.55		6.4×10^{-6}		155°F					"	
0500	9.55		6.8×10^{-6}		155°F					"	
0600	9.55		6.7×10^{-6}		155°F					"	
0700	9.60		5.8×10^{-6}		155°F					"	
[illegible]00	9.55		3.9×10^{-6}		155°F					"	
0905	9.57		2×10^{-5}		119°F					"	
	temperature was turned down @ 0940 (6-23) to 70° then 1 hour later -35°										
1050	9.55		1×10^{-5}		32°F					"	
1100	9.58		3×10^{-5}		25°F					"	
1200	9.58		3×10^{-5}		-20°F					"	
1230	9.58		3×10^{-5}		-35°F					"	
1305	9.59		1.9×10^{-5}		-35°F					"	
1400	9.59		1.6×10^{-5}		-35°F					"	
1500	9.59		1.2×10^{-5}		-35°F					"	
1600	9.59		1.6×10^{-5}		-35°F					"	
1700	9.59		1.8×10^{-5}		-35°F					"	
1800	9.59		1.0×10^{-5}		-29°F					"	
1000	9.60				-35°F					"	
2000	9.60		1.4×10^{-5}		-35°F					"	
[illegible]00	9.60		1.4×10^{-5}		-35°F					"	
2200	9.50		1.4×10^{-5}		-35°F			cycling: on=2sec, off=2 sec.			
2300	9.50		1.4×10^{-5}		-35°F			cycling: on=3sec, off=10sec.			
2400	9.50		1.4×10^{-5}		-35°F			cycling: on=5sec, off=5 sec.			
0100	9.50		5.7×10^{-6}		-35°F			cycling: on=3sec, off=2 sec.			
0200	9.50		5.3×10^{-6}		-35°F			cycling: on=3sec, off=3 sec.			
0300	9.50		6.3×10^{-6}		-35°F			cycling: on=3 sec, off=3 sec.			
TIME TO OUT VOLTAGE											
CAPACITY TO OUT VOLTAGE											

PREPARED BY /S/ Phil Woodcock

FORM NO. 5-73

EXIDE MISSILE & ELECTRONICS DIVISION ESB INCORPORATED — Exide — TEST DATA SHEET

TEMPERATURE	-40°F to +160°F	SPEC. NO.	NASA EXHIBIT "A"	T. W.O. NO.	69-056
CURRENT	0.5 amps	ITEM TESTED	Model 347	J. O. NO.	84068
OUT VOLTAGE	9.0 Volts	PROJ. ENG.	W. D. Bull, Jr.	SERIAL NO.	X3
				DATE	6-25-69

Time	Battery Voltage		Pressure (TORR)		Indicator Temp.				Heater On	Heater Off	
0400	9.50		5.7×10^{-6}		-35°F				2 sec.	3 sec.	
0500	9.50		6.3×10^{-6}		-35°F				2 sec.	3 sec.	
0600	9.50		9.4×10^{-6}		-35°F				2 sec.	5 sec.	
0700	9.45		4.8×10^{-6}		-35°F				6 sec.	3 sec.	
0800	9.45		8.0×10^{-6}		-35°F				3 sec.	3 sec.	
0900	9.45		8.2×10^{-6}		-35°F						
	temperature changed from -35°F to +60°F /made @ 0935/9.42 volts										
1000	9.47		5.5×10^{-6}		+60°F			on 3 sec./heaters off 5 sec.			
1100	9.57		4.6×10^{-6}		110°F				heaters off		
	temperature changed from 110°F to 155°F at 1135								heaters off		
1200	9.59		5×6^{-5}		155°F				heaters off		
1300	9.59		1.1×10^{-5}		155°F				heaters off		
1400	9.58		1.3×10^{-5}		155°F				heaters off		
1500	9.58		1.3×10^{-5}		155°F				heaters off		
1600	9.58		1.4×10^{-5}		155°F				heaters off		
1700	9.50		1.2×10^{-5}		155°F				heaters off		
1800	9.55		1.8×10^{-6}		155°F				heaters off		
1900	9.55		1.7×10^{-6}		155°F				heaters off		
2000	9.55		1.2×10^{-5}		155°F				heaters off		
2100	9.57		1.2×10^{-5}		155°F				heaters off		
2200	9.57		1.0×10^{-5}		155°F				heaters off		
2300	9.57		1.1×10^{-5}		155°F				heaters off		
2400	9.57		1.0×10^{-5}		155°F				heaters off		
0100	9.57		1.4×10^{-5}		155°F				heaters off		
0200	9.50		5.7×10^{-6}		155°F				heaters off		
0300	9.58		1.8×10^{-5}		155°F				heaters off		
0400	9.58		1.3×10^{-5}		155°F				heaters off		
0500	9.58		1.0×10^{-5}		155°F				heaters off		
0600	9.58		$.9\times10^{-5}$		155°F				heaters off		
TIME TO OUT VOLTAGE											
CAPACITY TO OUT VOLTAGE											

PREPARED BY /S/ Phil Woodcock

EXIDE MISSILE & ELECTRONICS DIVISION ESB INCORPORATED	Exide	TEST DATA SHEET	T. W.O. NO. 69-056
TEMPERATURE	-40°F to +160°F	SPEC. NO. NASA EXHIBIT "A"	J.O. NO. 84068
CURRENT	0.5 amps	ITEM TESTED Model 347	SERIAL NO. X3
OUT VOLTAGE	9.0 Volts	PROJ. ENG. W. D. Bulla, Jr.	DATE 6-25-69

Time	Battery Voltage		Pressure (TORR)		Indicator Temp.				Heater On	Heater Off	
0700	9.58		$.9\times10^{-5}$		155°F					X	
0800	9.58		1.4×10^{-5}		155°F					X	
0900	9.58		1×10^{-5}		157°F					off	
	temperature changed from 155°F to 80°F at 28.5 hrs. (0931)										
1000	9.56		2.3×10^{-5}		80°F					off	
	temperature changed from 80°F to 30°F @ 1032										
1100	9.58		2.4×10^{-5}		30°F					off	
	temperature changed from 30°F to -20° @ 1132										
1200	9.58		2.2×10^{-5}		-20°F					off	
	temperature changed from -20°F to -35 F at 1230										
1300	9.59		1.5×10^{-5}		-35°F					off	
1400	9.59		1.2×10^{-5}		-35°F					off	
1500	9.59		1.3×10^{-5}		-35°F					off	
1600	9.59		1.8×10^{-5}		-35°F					off	
1700	9.59		1.6×10^{-5}		-35°F					off	
1800	9.59		1.5×10^{-5}		-35°F					off	
1900	9.59		1.5×10^{-5}		-35°F					off	
2000	9.58		1.5×10^{-5}		-35°F					off	
2100	9.59		1.4×10^{-5}		-35°F					off	
2200	9.40		1.4×10^{-5}		-35°F			heater	on 5 sec.	off 5	sec.
2300	9.40		1.2×10^{-5}		-35°F			heater	on 2 sec.	off 1	sec.
2400	9.45		8.8×10^{-6}		-35°F			heater	on 9 sec.	off 9	sec.
0100	9.45		1.0×10^{-6}		-35°F				off 7 sec	on 3	sec
0200	9.45		2.5×10^{-6}		-35°F				on 4 sec.	off 5	sec.
0300	9.45		6.6×10^{-6}		-35°F				on 4 sec.	off 4	sec.
0400	9.41		6.4×10^{-6}		-35°F				on 4 sec	off 2	sec
0500	9.41		3.6×10^{-6}		-35°F				on 5 sec	off 3	sec.
0600	9.40		6.8×10^{-6}		-35°F				on 2 sec.	off 2	sec.
0700	9.40		5.0×10^{-6}		-35°F				on 3 sec.	off 3	sec
0800	9.40		8.0×10^{-6}		-35°F				on 5 sec.	off 5	sec.
TIME TO OUT VOLTAGE											
CAPACITY TO OUT VOLTAGE											

PREPARED BY /S/ Phil Woodcock

FORM NO. 1-13

EXIDE MISSILE & ELECTRONICS DIVISION ESB INCORPORATED	Exide	TEST DATA SHEET	T. W. O. NO. 69-056
TEMPERATURE -40°F to +160°F	SPEC. NO. NASA EXHIBIT "A"		J. O. NO. 84068
CURRENT 0.5 amps	ITEM TESTED Model 347		SERIAL NO. X3
OUT VOLTAGE 9.0 Volts	PROJ. ENG. W. D. Bulla, Jr.		DATE 6-27-69

Time	Battery Voltage		Pressure (TORR)		Indicator Temp.				Heaters On	Heaters Off	
0900	9.39		4.2×10^{-5}		-35°F				5 sec.	5 sec.	
	temperature changed from -35°F to +60°F @ 0930										
1000	9.45		5.8×10^{-6}		60°F				heater off		
	temperature changed from 60°F to 110°F @ 1034										
1100	9.50		7.4×10^{-6}		110°F				heater off		
	temperature changed from 110°F to 155°F @ 1134										
1200	9.55		1.0×10^{-5}		155°F					off	
1300	9.55		1.3×10^{-5}		155°F					off	
1410	9.55		1.2×10^{-5}		155°F					off	
1500	9.55		1.0×10^{-5}		155°F					off	
1700	9.55		1.0×10^{-5}		155°F					off	
1800	9.55		3.6×10^{-5}		155°F					off	
01400	9.55		1.0×10^{-5}		155°F					off	
0200	9.55		3.8×10^{-5}		155°F					off	
02100	9.55		1.3×10^{-5}		155°F					off	
02200	9.55		1.0×10^{-5}		155°F					off	
2300	9.55		1.3×10^{-5}		155°F					off	
2400	9.55		3.7×10^{-5}		155°F					off	
0100	9.55		5.2×10^{-5}		155°F					off	
0200	9.55		4.8×10^{-5}		155°F					off	
0300	9.55		3.2×10^{-5}		155°F					off	
0400	9.55		1.0×10^{-5}		155°F					off	
0500	9.55		3.6×10^{-5}		155°F					off	
0600	9.55		3.6×10^{-5}		155°F					off	
0700	9.55		3.6×10^{-5}		155°F					off	
0800	9.55		3.4×10^{-5}		155°F					off	
0900	9.55		2.1×10^{-5}		155°F					off	
	temperature changed from 155°F to 80°F @ 0934										
1000	9.53		1.8×10^{-5}		80°F					off	
	temperature changed from 80°F to 25°F @ 1034										
TIME TO OUT VOLTAGE											
CAPACITY TO OUT VOLTAGE											

PREPARED BY /S/ Phil Woodcock

EXIDE MISSILE & ELECTRONICS DIVISION ESB INCORPORATED — Exide — TEST DATA SHEET

TEMPERATURE	-40°F to+160°F	SPEC. NO.	NASA EXHIBIT "A"	J.O. NO.	84068
CURRENT	0.5 amps	ITEM TESTED	Model 347	SERIAL NO.	X3
CUT VOLTAGE	9.0 Volts	PROJ. ENG.	W. D. Bulla, Jr.	DATE	6-28-69
				T.W.O. NO.	69-056

Time	Battery Voltage		Pressure (TORR)		Indicator Temp.				Heater On	Heater Off	
1100	9.54		2.4×10^{-5}		30°F					off at time	
	temperature changed from -20°F to -40°F (35) @ 1130										
1200	9.56		1.8×10^{-5}		-35°F				not on		
1300	9.55		1.5×10^{-5}		-35°F				not on		
1400	9.55		1.4×10^{-5}		-35°F				not on		
1500	9.55		1.4×10^{-5}		-35°F				not on		
1600	9.55		8.6×10^{-6}		-35°F				not on		
1700	9.53		9.2×10^{-6}		-35°F				not on		
1800	9.57		9.6×10^{-6}		-35°F				not on		
1900	9.53		9.6×10^{-5}		-35°F				not on		
2000	9.52		9.6×10^{-6}		-35°F					off	
2100	9.50		4×10^{-6}		-35°F					off-@ 2114 heater on	
2200	9.40		3×10^{-6}		-35°F				heater on	on time 3 sec.	
2300	7.80		2.2×10^{-6}		-35°F			heater on cycling continuously			
2400	7.70		2.2×10^{-6}		-35°F			heater on cycling continuously			
0100	7.65		2.4×10^{-6}		-35°F				heater	cycling	
0200	6.10		2.2×10^{-6}		-35°F				heater	off	
0300	6.10		5.0×10^{-6}		-35°F				heater	on	
0400	6.05		2.0×10^{-6}		-35°F				heater	off for 1 sec on for 5 min.	
0500	6.01		4.3×10^{-6}		-35°F				heater	on	
	temperature changed to +75°F @ 0510										
0600	6.00		5.3×10^{-6}		+75°F				heater	on-off @0629	
0700	6.15		3.2×10^{-6}		+75°F				heater	cycling@0700	
0800	6.25		5.3×10^{-6}		+75°F					off	
1500	11.7		4.3×10^{-6}		+75°F					off	
1600	11.7		4.3×10^{-6}		+75°F					off	
1700	11.7		4.0×10^{-6}		+75°F					off	
1800	11.7		4.6×10^{-6}		+75°F					off	
1900	11.7		4.0×10^{-6}		+75°F					off	
TIME TO CUT VOLTAGE											
CAPACITY TO CUT VOLTAGE											

PREPARED BY /S/ Phil Woodcock

EXIDE MISSILE & ELECTRONICS DIVISION — ESB INCORPORATED — Exide — TEST DATA SHEET

T.W.O. NO. 69-056			
TEMPERATURE -40°F to+160°F	SPEC. NO. NASA EXHIBIT "A"	J.O. NO. 84068	
CURRENT .35 amps	ITEM TESTED Model 347	SERIAL NO. X3	
OUT VOLTAGE 9.0 Volts	PROJ. ENG. W. D. Bulla, Jr.	DATE 6-29-69	

Time	Battery Voltage		Pressure (TORR)		Indicator Temp.				Heater On	Heater Off	
2000	11.70		4.2×10^{-6}		75°F					off	
2100	11.70		4.5×10^{-6}		75°F					off	
2200	11.75		5.1×10^{-6}		75°F					off	
2300	11.80		7.4×10^{-6}		75°F					off	
2400	11.89				75°F						
TIME TO OUT VOLTAGE											
CAPACITY TO OUT VOLTAGE											

PREPARED BY /S/ Phil Woodcock

EXIDE MISSILE & ELECTRONICS DIVISION — ESB INCORPORATED — Exide — TEST DATA SHEET

TEMPERATURE	-35°F to 155°F	SPEC. NO.	NASA EXHIBIT "A"	T. W.O. NO.	69-056
CURRENT	0.5 amps	ITEM TESTED	Model 347	J. O. NO.	84068
OUT VOLTAGE	9.0 Volts	PROJ. ENG.	W. D. Bulla, Jr.	SERIAL NO.	X3
				DATE	6-30-69

Time	Battery Voltage		Pressure (TORR)		Indicator Temp.				Heater On	Heater Off	
	6-30-69 the Battery was put on charge and cut of @ 12.2 volts, where it remained at 70°F until Monday morning. I (Woodrock) changed temperature down to 25°F @ 1430, starting to go down to col temp.										
1143	11.01		$.06 \times 10^{-4}$		-30°F				heater off		
1900	11.0		4.2×10^{-5}		-30°F					X	
2000	10.9		4.2×10^{-5}		-30°F				heater off but resembles cycling at intervals		
[illegible]00	10.92		4×10^{-5}		-30°F					X	
2200	10.85		4.2×10^{-5}		-30°F					X cycling	
2300	10.8		4.0×10^{-5}		-30°F					X cycling	
2400	10.8		3.5×10^{-5}		-30°F					X cycling	
0100	10.7		3.8×10^{-5}		-30°F					X cycling	
0200	10.6		4.0×10^{-5}		-30°F					X cycling	
0300	9.85		3.0×10^{-5}		-30°F					X cycling	
0400	9.7		3.0×10^{-5}		110°F					X cycling	
0500	9.6		3.4×10^{-5}		155°F					X cycling	
0600	9.6		3.2×10^{-5}		155°F					X cycling	
0700	9.65		4.5×10^{-5}		155°F					X cycling	
0800	9.65		4.5×10^{-5}		155°F					X cycling	
0900	9.6		6.5×10^{-5}		155°F					off	
1000	9.6		4.2×10^{-5}		155°F					off	
1100	9.6		5.5×10^{-5}		155°F					off	
[illegible]200	9.6		6.2×10^{-5}		155°F					off	
1300	9.55		8.9×10^{-5}		155°F					off	
1400	9.65		1.0×10^{-4}		155°F					off	
1500	9.50		9.0×10^{-5}		155°F					off	
	temperature changed @ 1445 from 155°F to 80°F										
TIME TO OUT VOLTAGE											
CAPACITY TO OUT VOLTAGE											

PREPARED BY /S/ Phil Woodcock

EXIDE MISSILE & ELECTRONICS DIVISION ESB INCORPORATED	Exide TEST DATA SHEET	T. W.O. NO.	69-056
TEMPERATURE: -35°F to 155°F	SPEC. NO.: NASA EXHIBIT "A"	J.O. NO.	84068
CURRENT: 0.5 amps	ITEM TESTED: Model 347	SERIAL NO.	X3
OUT VOLTAGE: 9.0 Volts	PROJ. ENG.: W. D. Bulla, Jr	DATE	7-1-69

Time	Battery Voltage		Pressure (TORR)		Indicator Temp.				Heater On	Heater Off	
	temperature changed @ 1545 from 80°F to 30°F										
1600	9.5		8.1×10^{-5}		30°F					off	
	temperature changed @ 1630 from 30°F to -25°F										
1700	temperature changed to -35°F on indicator										
1700	9.5		1.0×10^{-5}		-35°F					off	
1800	9.5		5.6×10^{-5}		-35°F					off	
1900	9.44		5.4×10^{-5}		-35°F					off	
[illegible]00	9.4		6.0×10^{-5}		-35°F					off	
2100	9.4		5.0×10^{-5}		-35°F					off	
2200	9.45		4.2×10^{-5}		-35°F					off	
2300	9.45		3.2×10^{-5}		-35°F					off	
2400	9.45		3.5×10^{-5}		-35°F					off	
0100	9.40		3.0×10^{-5}		-35°F					off	
0200	9.40		3.0×10^{-5}		-35°F					off	
0300	9.40		3.8×10^{-5}		-35°F					off	
0400	9.45		3.2×10^{-5}		-35°F					off	
0500	9.40		3.2×10^{-5}		-35°F					off	
0600	9.40		3.2×10^{-5}		-35°F					off	
0700	9.38		3.2×10^{-5}		-35°F					off	
0800	9.38		3.8×10^{-5}		-35°F					off	
0900	9.35		4.7×10^{-5}		-35°F				on		
1015	9.35		5.2×10^{-5}		-35°F					off	
[illegible]100	9.32		5.7×10^{-5}		-35°F				on		
1200	9.25		6×10^{-5}		-35°F				on		
1300	7.75		6.7×10^{-5}		+40°F						
1410	5.1		1.0×10^{-4}		+40°F				on		
1500	4.8		1.0×10^{-4}		+75°F						
TIME TO OUT VOLTAGE											
CAPACITY TO OUT VOLTAGE											

PREPARED BY /S/ Phil Woodcock

EXIDE MISSILE & ELECTRONICS DIVISION, ESB INCORPORATED	Exide	TEST DATA SHEET	T. W.O. NO. 69-056
TEMPERATURE: -40°F to+160°F	SPEC. NO.: NASA EXHIBIT "A"		J.O. NO. 84068
CURRENT: 0.5 amps	ITEM TESTED: Model 347		SERIAL NO. X3
OUT VOLTAGE: 9.0 Volts	PROJ. ENG.: W. D. Bulla, Jr.		DATE 6-18-69

Discharge	No. 1	9.60 OCV No. 2	9.60 No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No 10	No 11
Date	7-1-69	7-1-69									
Clock Time	0230	0230									
Load (ohms)	18.22	18.34									
Chamber Temp. Start	-24°F	155°									
10 min.	-26°F	155°									
20 min.	-26°F	155°									
[illegible] min.	-26°F	155°									
Chamber Pressure St.	3.6×10^{-5}	155°									
10 min. (TORR)	3.0×10^{-5}	1.0×10^{-4}									
20 min. (TORR)	3.0×10^{-5}	1.0×10^{-4}									
30 min. (TORR)	3.0×10^{-5}	1.0×10^{-4}									
Timer Time	on 0	on 0									
0.5 min.	7.65	9.37									
1.0	9.60	9.36									
1.5	9.60	9.36									
2.0	9.58	9.36									
2.5	9.55	9.35									
3.0	9.55	9.35									
4.0	9.50	9.35									
5.0	9.48	9.34									
6.0	9.45	9.34									
[illegible].0	9.40	9.33									
8.0	9.38	9.33									
9.0	9.36	9.33									
10.0	9.35	9.33									
15.0	9.31	9.33									
20.0											
25.0											
30.0											
Timer Time	15.0	15.0									
TIME TO OUT VOLTAGE	X	X									
CAPACITY TO OUT VOLTAGE	X	X									

PREPARED BY /S/ Phil Woodcock

APPENDIX B

TEST DATA

EXIDE MISSILE & ELECTRONICS DIVISION ESB INCORPORATED	Exide TEST DATA SHEET	T. W.O. NO. 69-056
TEMPERATURE -40°F to +160°F	SPEC. NO. NASA EXHIBIT "A"	J.C. NO. 84068
CURRENT 0.5 amp	ITEM TESTED Model 347	SERIAL NO. X4
OUT VOLTAGE 9.0 Volts	PROJ. ENG. W. D. Bulla, Jr.	DATE Noted

OCV Discharge	9.50 No. 1	9.59 No. 2	9.50 No. 3	9.60 No. 4	9.40 No. 5	9.60 No. 6	9.40 No. 7	11.10V No. 8	10.30 No. 9	No. 10	No. 11
Date	9-17	9-18	9-19	9-20	9-21	9-22	9-23	9-27	9-28	9-29	9-30-69
Clock Time	1000	1000	1000	1000	1000	1100	1000	1033	1000	1030	1000
Load (ohms)	18.22	18.34	18.22	18.34	18.22	18.34	18.22	18.34	18.22	18.34	18.22
Chamber Temp. Start	-35°F	155°F	-35°	155°F	-35°	155°F	-35°F	155°F	-35°F	155°F	-35°F
10 Min.	-35°F	155°	-35°	155°F	-35°	155°F	-35°F	155°F	-35°F	155°F	-35°F
20 Min.	-35°F	155°	-35°	155°F	-35°	155°F	-35°F	155°F	-35°F	155°F	-35°F
30 Min.	-35°F	155°	-35°	155°F	-35°	155°F	-35°F	155°F	-35°F	155°F	-35°F
Chamber Pressure Start	2×10^{-5}	5×10^{-5}	1×10^{-5}	1.9×10^{-5}	1.1×10^{-5}	2.9×10^{-5}	1.9×10^{-5}	2×10^{-4}	3.7×10^{-5}	6×10^{-5}	3×10^{-5}
10 Min. (TORR)	2×10^{-5}	1×10^{-5}	$.8\times10^{-5}$	1.6×10^{-5}	1.6×10^{-5}	1.1×10^{-5}	1.7×10^{-5}	7.2×10^{-5}	1.3×10^{-4}	4×10^{-5}	1×10^{-5}
20 Min. (TORR)	2×10^{-6}	3×10^{-5}	$.7\times10^{-5}$	2.1×10^{-5}	$.05\times10^{-5}$	1×10^{-5}	1.4×10^{-5}	5.8×10^{-5}	2.4×10^{-5}	5×10^{-5}	1×10^{-5}
30 Min. (TORR)	2×10^{-6}	4×10^{-5}	$.8\times10^{-5}$	3.0×10^{-5}	$.06\times10^{-5}$	1×10^{-5}	1.4×10^{-5}	5.4×10^{-5}	2.2×10^{-5}	4×10^{-5}	1×10^{-5}
Timer Time	0	0	0	0	0	0	0	0	0	0	0
0.5 Min.	9.20	9.40	9.10	9.40	9.10	9.36	9.03	10.94	9.50	9.50	9.20
1.0	9.20	9.38	9.18	9.40	9.10	9.35	9.00	10.92	9.50	9.50	9.21
1.5	9.20	9.38	9.20	9.39	9.18	9.35	9.08	10.915	9.50	9.50	9.21
2.0	9.21	9.35	9.20	9.38	9.20	9.34	9.10	10.91	9.48	9.50	9.21
2.5	9.21	9.35	9.20	9.38	9.20	9.33	9.10	10.903	9.47	9.50	9.21
3.0	9.21	9.35	9.17	9.37	9.20	9.31	9.10	10.90	9.47	9.49	9.21
4.0	9.21	9.34	9.22	9.36	9.15	9.30	9.10	10.90	9.46	9.49	9.21
5.0	9.21	9.32	9.22	9.33	9.20	9.30	9.10	10.90	9.45	9.49	9.21
6.0	9.21	9.32	9.20	9.32	9.20	9.29	9.10	10.898	9.44	9.48	9.21
7.0	9.21	9.31	9.20	9.32	9.20	9.28	9.10	10.897	9.43	9.47	9.21
8.0	9.21	9.31	9.20	9.31	9.20	9.27	9.10	10.88	9.43	9.46	9.21
9.0	9.21	9.30	9.21	9.305	9.20	9.25	9.10	10.875	9.43	9.45	9.21
10.0	9.21	9.30	9.20	9.305	9.20	9.25	9.10	10.875	9.42	9.45	9.21
15.0	9.20	9.30	9.20	9.30	9.20	9.24	9.08	10.82	9.40	9.41	9.20
20.0	9.20	9.30	9.20	9.30	9.20	9.22	9.03	10.799	9.40	9.40	9.20
25.0	9.20	9.29	9.20	9.30	9.20	9.22	9.03	10.73	9.39	9.40	9.20
30.0	9.20	9.29	9.20	9.30	9.18	9.22	9.03	10.70	9.37	9.38	9.20
Timer Cell	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
TIME TO OUT VOLTAGE											
CAPACITY TO OUT VOLTAGE											

PREPARED BY /S/ Phil Woodcock

FORM NO. 5-73

EXIDE MISSILE & ELECTRONICS DIVISION ESB INCORPORATED	Exide TEST DATA SHEET	T. W.O. NO. 69-056
TEMPERATURE -40°F to +160°F	SPEC. NO. NASA EXHIBIT "A"	J.O. NO. 84068
CURRENT 0.5 amp	ITEM TESTED Model 347	SERIAL NO. X4
OUT VOLTAGE 9.0 Volts	PROJ. ENG. W. D. Bulla, Jr.	DATE Noted

OCV Discharge	9.60 No. 12		No. 13		9.45 No. 14						
Date	10-1-69		10-2-69		10-3-69		Continue discharge until voltage				
Clock Time	1035		1020		1035		reaches 8.5 volts				
Load (ohms)	18.34		18.22		18.34		Time		Voltage		Load
Chamber Temp. Start	155°F		-35°F		155°F		35 min.		9.20		18.34
10 Min.	"		"		"		40 min.		"		"
20 Min.	"		"		"		45 min.		"		"
30 Min.	"		"		"		50 min.		"		"
Chamber Pressure Start	$2x10^{-5}$		$1x10^{-5}$		$2.3x10^{-5}$		55 min.		"		"
10 Min. (TORR)	$3.9x10^{-5}$		$8x10^{-6}$		$2.9x10^{-5}$		60 min.		9.19		"
20 Min. (TORR)	$2.9x10^{-5}$		$7x10^{-6}$		$2.3x10^{-5}$		65 min.		9.18		"
30 Min. (TORR)	$3x10^{-5}$		$7x10^{-6}$		$2.6x10^{-5}$		70 min.		9.17		"
Timer Time	0		0		0		80 min.		9.15		"
0.5 min.	9.31		9.10		9.24		85 min.		9.14		"
1.0	9.30		9.10		9.24		90 min.		9.13		"
1.5	9.30		9.10		9.24		95 min.		9.13		"
2.0	9.30		9.10		9.24		100 min.		9.11		"
2.5	9.30		9.10		9.23		105 min.		9.10		"
3.0	9.30		9.11		9.23		120 min.		9.0		"
4.0	9.30		9.12		9.23		123 Min.		8.90		
5.0	9.30		9.12		9.23		126 min.		8.80		
6.0	9.29		9.12		9.23						
7.0	9.29		9.12		9.22						
8.0	9.29		9.12		9.22						
9.0	9.29		9.12		9.22						
10.0	9.29		9.12		9.22						
15.0	9.28		9.12		9.21						
20.0	9.27		9.11		9.20						
25.0	9.25		9.10		9.20						
30.0	9.25		9.10		9.20						
Timer Time	30.0		30.0		30.0						
TIME TO OUT VOLTAGE						*Time to 9.0V 119 min 55 sec.					
CAPACITY TO OUT VOLTAGE						Time to 8.50V 128 min. 43 Sec.					

PREPARED BY /S/ Phil Woodcock

EXIDE MISSILE & ELECTRONICS DIVISION — ESB INCORPORATED — Exide

TEST DATA SHEET

TEMPERATURE -40°F to +160°F	SPEC. NO. NASA	T. W.O. NO.	69-056
CURRENT 0.5 amp	ITEM TESTED 347	J.O. NO.	84068
OUT VOLTAGE 9.0V	PROJ. ENG. W. D. Bulla, Jr.	SERIAL NO.	X4
		DATE	9-16-69

Time	Volts		Temp		Pressure			Heater ON	Heater OFF		
800	11.1		+10		5×10^{-5}				x		
900	11.1		-20						x		
1000	11.1		-35		2×10^{-5}				x		
1230	11.1		-35		2×10^{-6}			x			
1730	10.5		-35		1.5×10^{-5}				x		
2145	9.5		-35		7×10^{-5}				x		
2309	9.5		-35		6.9×10^{-5}				x		
[illegible]18	9.5		-35		6.9×10^{-5}				x		
0155	9.5		-35		4.8×10^{-5}				x		
0345	9.5		-35		3.5×10^{-5}				x		
0545	9.5		-35		2.8×10^{-5}				x		
0725	9.5		-35		2.9×10^{-5}				x		
0825	9.5		-35		3×10^{-5}				x		
0925	9.5	9.38	-35		3×10^{-5}			x			
1000	9.5	9.38	-35		2×10^{-5}			x			
1030	9.5	9.42	+60		2×10^{-5}						
1100	9.5										
1200	9.56		110								
1300	9.58		155								
1400	9.58										
1500	9.58		155		3×10^{-5}						
1600	9.58		155		3×10^{-5}						
[illegible]00	9.55		155		2.8×10^{-5}				x		
1800	9.58		155		3.4×10^{-5}						
1900	9.58		155		4×10^{-5}						
2000	9.58		155		4×10^{-5}						
2100	9.58		155		4×10^{-5}						
0035	9.58		155		5.9×10^{-5}				x		
0130	9.58		155		4.2×10^{-5}				x		
TIME TO OUT VOLTAGE											
CAPACITY TO OUT VOLTAGE											

PREPARED BY /S/ Phil Woodcock

EXIDE MISSILE & ELECTRONICS DIVISION — ESB INCORPORATED	Exide	TEST DATA SHEET		T. W.O. NO.	69-056
TEMPERATURE	-40°F to +160°F	SPEC. NO.	NASA	J.O. NO.	84068
CURRENT	0.5 amps	ITEM TESTED	Model 347	SERIAL NO.	X4
OUT VOLTAGE	9.0 Volts	PROJ. ENG.	W. D. Bulla, Jr.	DATE	9-18-69

Time	Volts	Temp.	Pressure	Heater On	Heater Off
0230	9.59	155°	4.6×10^{-5}		X
0330	9.58	155°	4.8×10^{-5}		X
0430	9.58	155°	4.4×10^{-5}		X
0530	9.58	155°	4.5×10^{-5}		X
0630	9.58	155°	4.7×10^{-5}		X
1100	9.55	75°	5×10^{-5}		X
1[illegible]55	9.60	-25°	1.2×10^{-5}		X
1810	9.60	-35°	1.2×10^{-5}		X
1909	9.60	-35°	2.7×10^{-5}		X
2004	9.60	-35°	5.7×10^{-5}		X
2100	9.60	-35°	5.7×10^{-6}		X
2214	9.60	-34°	3.0×10^{-5}		X
2309	9.42-9.5	-20°	2.0×10^{-5}	cycling	
0010	9.41-9.5	-30°	4.8×10^{-6}	cycling	
0105	2.4-9.5	-30°	1.9×10^{-5}	cycling	
0140	9.5-9.59	-30°	1.4×10^{-5}	cycling	
0230	9.4-9.5	-30°	1.5×10^{-5}	cycling	
0335	9.4-9.5	-30°	1.5×10^{-5}	cycling	
0430	9.4-9.5	-30°	1.5×10^{-5}	cycling	
0630	9.4-9.5	-30°	1.6×10^{-5}	cycling	
0728	9.4-9.5	-30°	1.6×10^{-5}	cycling	
[illegible]829	9.4-9.5	-30°	1.6×10^{-5}	cycling	
[illegible]800	9.6	155°	4×10^{-5}		X
1900	9.6	155°	1.9×10^{-5}		X
2000	9.6	155°	1.6×10^{-5}		X
2100	9.6	155°	1.6×10^{-5}		X
2330	9.6	155°	4.6×10^{-5}		X
0030	9.6	155°	1.8×10^{-5}		X
0130	9.6	155°	2.2×10^{-5}		X
TIME TO OUT VOLTAGE					
CAPACITY TO OUT VOLTAGE					

PREPARED BY /S/ Phil Woodcock

EXIDE MISSILE & ELECTRONICS DIVISION ESB INCORPORATED	Exide	TEST DATA SHEET	T. W. O. NO. 69-056
TEMPERATURE	-40°F-+160°F	SPEC. NO. NASA	J. O. NO. 84068
CURRENT	0.5 amps	ITEM TESTED Model 347	SERIAL NO. X4
OUT VOLTAGE	9.0 Volts	PROJ. ENG. W. D. Bulla, Jr.	DATE 9-20-69

Time	Volts	Temp.	Pressure	Heater On	Heater Off
0236	9.6	155°	2.1×10^{-5}		X
0332	9.6	155°	2.2×10^{-5}		X
0430	9.6	155°	2.0×10^{-5}		X
0530	9.6	155°	2.3×10^{-5}		X
0630	9.6	155°	2.0×10^{-5}		X
0730	9.6	155°	2.2×10^{-5}		X
0830	9.6	155°	2.0×10^{-5}		X
[illegible]6	9.6	155°	1.9×10^{-5}		X
1032	9.51	155°	2.8×10^{-5}		X
1057	9.57	155°	2.6×10^{-5}		X
1125	9.58	75°	6.8×10^{-5}		X
1145	9.57	75°	4.8×10^{-5}		X
1202	9.59	25°	3.8×10^{-5}		X
1258	9.59	25°	3.2×10^{-5}		X
1310	9.59	-20°F	2.0×10^{-5}		X
1330	9.59	-35°F	1.1×10^{-5}		X
1401	9.595	-35°F	1.7×10^{-5}		X
1420	9.595	-35°F	1.0×10^{-5}		X
2345	9.45	-35°F	1.9×10^{-5}	X	X cycling
0045	9.46	-35°F	1.8×10^{-5}	X	X
0145	9.46	-35°F	1.9×10^{-5}	X	X
0245	9.46	-35°F	1.8×10^{-5}	X	X
[illegible]45	9.40	-35°F	1.8×10^{-5}		X
0445	9.46	-35°F	1.8×10^{-5}	X	X
0600	9.48	-35°F	1.2×10^{-5}	X	X
0800	9.45	-35°F	1.2×10^{-5}	X	X
0900	9.47	-35°F	1.6×10^{-5}	X	X
1000	9.45	-35°F	1.1×10^{-5}	X	X
1100	9.45	60°F	$.05 \times 10^{-5}$	X	X cycling
1200	9.45	110°	1.2×10^{-5}	X	X cycling
TIME TO 1300 OUT VOLTAGE	9.57	155°	1.2×10^{-5}		off
CAPACITY TO OUT VOLTAGE					

PREPARED BY /S/ Phil Woodcock

EXIDE MISSILE & ELECTRONICS DIVISION — ESB INCORPORATED	Exide	TEST DATA SHEET	T. W.O. NO. 69-056
TEMPERATURE -40°F - 160°F	SPEC. NO. NASA		J.O. NO. 84068
CURRENT 0.5 amps	ITEM TESTED Model 347		SERIAL NO. X4
OUT VOLTAGE 9.0 Volts	PROJ. ENG. W. D. Bulla, Jr.		DATE 9-22-69

Time	Volts		Temp.		TORR				Heater On	Off	
0812	9.60		155°		1×10^{-5}					X	
1100	9.60		155°		2.9×10^{-5}					X	
1200	9.55		80°		3.5×10^{-5}					X	
1430	9.58		-40°F		2.7×10^{-5}					X	
1510	9.59		-40°F		1.3×10^{-5}					X	
1750	9.50		-40°F		1.7×10^{-5}				X	X cycling	
1950	9.45		-40°F		1.5×10^{-5}				X	X	
2112	9.44		-40°F		1.4×10^{-5}				X	X	
2250	9.42		-40°F		1.5×10^{-5}				X	X	
2350	9.44		-40°F		1.4×10^{-5}				X	X	
0055	9.44		-40°F		1.4×10^{-5}				X	X	
0155	9.44		-40°F		1.6×10^{-5}				X	X	
0238	9.44		-40°F		1.4×10^{-5}				X	X	
0331	9.44		-40°F		1.4×10^{-5}				X	X	
0424	9.44		-40°F		1.4×10^{-5}				X	X	
0530	9.44		-40°F		1.4×10^{-5}				X	X	
0637	9.44		-40°F		1.1×10^{-5}				X	X	
0739	9.45		-40°F		1.5×10^{-5}				X	X	
1000	9.40		-40°F		1.9×10^{-5}				X	X	
1100	9.36		80°F		2.0×10^{-5}				X	X	
1235	9.44		80°F		1.9×10^{-5}				X	X	
1300	9.45		80°F		2.0×10^{-5}				X	X	
1420	9.45		80°F		2.4×10^{-5}				X	X	
[illegible]22	9.55		155°		1×10^{-5}				X	off	
TIME TO OUT VOLTAGE											
CAPACITY TO OUT VOLTAGE											

PREPARED BY /S/ Phil Woodcock

FORM NO. 5.73

EXIDE MISSILE & ELECTRONICS DIVISION — ESB INCORPORATED — Exide

TEST DATA SHEET

TEMPERATURE	80°F	SPEC. NO.	EWOS 9-23-69	T. W.O. NO.	69-056
CURRENT	11.64 CP .35 amps	ITEM TESTED	347 Battery	J.O. NO.	84068
OUT ~~VOLTAGE~~ Current	0.05 amp	PROJ. ENG.	W.D. Bulla, Jr.	SERIAL NO.	X4
				DATE	9-23-69

Time		S/N X4		Amps	
OCV		9.55		0	
on @ 1637		9.84		.35	
1725		9.90		.35	
1800		9.90		.35	
1900		10.33		.35	
1955		11.30		.23	
2056		11.45		.12	
[illegible]28		11.49		.11	
0130		11.50		.11	
0226		11.50		.102	
0325		11.50		.10	
0429		11.50		.09	
0530		11.50		.09	
0630		11.51		.09	
0726		11.53		.09	
0808		11.64		.11	
0840		11.64		.16	
1012		11.64		.16	
1110		11.64		.16	
1230		11.64		.16	
1330		11.64		.16	
1430		11.64		.16	
[illegible]30		11.64		.16	
1630		11.64		.17	
1730		11.64		.17	
1830		11.64		.16	
1930		11.64		.15	
2830		11.70		.14	Adjust voltage - was set @ approx. 11.80V
2033		11.59		.11	
2100		11.60		.11	
TIME TO OUT VOLTAGE					
CAPACITY TO OUT VOLTAGE					

PREPARED BY /S/ Phil Woodcock

FORM NO. 5.73

EXIDE MISSILE & ELECTRONICS DIVISION — ESB INCORPORATED — Exide

TEST DATA SHEET

TEMPERATURE 80°F	SPEC. NO. EWOS 9-23-69	T. W. O. NO. 69-056
CURRENT 11.04 CP .35 amp	ITEM TESTED 347 Battery	J. O. NO. 84068
~~Current~~ OUT VOLTAGE .05 amp	PROJ. ENG. W. D. Bulla, Jr.	SERIAL NO. X4
		DATE 9-25-69

Time		S/N X4		Amps	
0100		11.60		.082	
0159		11.60		.075	
0307		11.61		.07	
0400		11.61		.07	
0500		11.61		.065	
0530		11.63		.06	
0630		11.61		.06	
0730		11.61		.06	
0830		11.65		.05	
=		=		=	4.77 AH
0935		11.65		.05	Change C. P. to 11.80
0935		11.80		.15	
0955		11.80		.16	
1200		11.80		.08	
1300		11.80		.065	
1700		11.80		.04	
1800		11.80		.03	
2000		11.79		.06	
2100		11.79		.04	
0030		11.79		.10	
0130		11.79		.06	
0230		11.79		.07	
0315		11.80		.05	Reached C. P. @ 0315
0330		11.80		.04	
0430		11.80		.03	
0530		11.79		.04	
0630		11.79		.03	
0730		11.79		.03	
1015		11.80		.03	
		off @ 1015			
TIME TO CUT VOLTAGE					
CAPACITY TO CUT VOLTAGE					

PREPARED BY /S/ Phil Woodcock

FORM NO. 5 73

EXIDE MISSILE & ELECTRONICS DIVISION
ESB INCORPORATED

Exide

TEST DATA SHEET

TEMPERATURE -40°F to +160°F	SPEC. NO EWOS		J.O. NO. 84068
CURRENT	ITEM TESTED Model 347		SERIAL NO. X4
OUT VOLTAGE 9.0 Volts	PROJ. ENG. W. D. Bulla, Jr.		DATE 9-27-69

T. W.O. NO. 69-056

Time	Volts	Vac	Temp	Heater Cycling	Heater Off	
1226	11.01	1.5×10^{-4}	75°F		x	
1332	11.00	1.6×10^{-4}	25°F		x	
1402	11.00	6.0×10^{-5}	-35°F	?		Voltage
1435	11.03	1.0×10^{-4}	-35°F		x	
0100	10.85	6.0×10^{-5}	-35°F	X		Not much decrease in voltage but
0200	10.83	5.8×10^{-5}	-35°F	X		some
0300	10.80	5.1×10^{-5}	-35°F	X		
[illegible]30	10.80	3.7×10^{-5}	-35°F	X		
0600	10.45	3.1×10^{-5}	-30°F	X		
0640	9.90	3.1×10^{-5}	-30°F	X		
0730	10.30	1.9×10^{-5}	-30°F	X		
0830	10.30	3.7×10^{-5}	-35°F	X		
0930	10.30	3.7×10^{-5}	-35°F	X		
1000	10.30	3.6×10^{-5}	-35°F	X		
1100	9.80	3.0×10^{-5}	+60°F		x	
1200	9.80	3.0×10^{-5}	110°F		x	
1300	9.799	2.8×10^{-5}	155°F		x	
1400	9.80	3.4×10^{-5}	155°F		x	
1405	9.70		155°F	?		Faint voltemeter oscillations after
1407	9.74		155°F	?		initial 0.1 drop from 9.80 to 9.70
1409	9.70		155°F	?		at 1403. Chart was off in
1414	9.73		155°F	?		accordance with my instructions but
[illegible]34	9.71	3×10^{-5}	155°F			upon restarting graph, indirect
1452	9.70	2.6×10^{-5}	155°F		x	evidence was recorded to substantiate
1456	9.68			X		observations
TIME TO OUT VOLTAGE						
CAPACITY TO OUT VOLTAGE						

PREPARED BY /S/ Phil Woodcock

FORM NO 5 73

EXIDE MISSILE & ELECTRONICS DIVISION ESB INCORPORATED	Exide TEST DATA SHEET	T. W.O. NO. 69-056
TEMPERATURE -40 to +160°F	SPEC. NO. EWOS	J.O. NO. 84068
CURRENT	ITEM TESTED Model 347	SERIAL NO. X4
OUT VOLTAGE 9.0	PROJ. ENG. W. D. Bulla, Jr.	DATE 9-29-69

Time	Volts		Vac		Temp		Heater ON	OFF			
0819	9.75		6.8 x 10^{-5}		155°F			x			
2017	9.72		3.5 x 10^{-5}		-35°F			x			
0030	9.72		4.2 x 10^{-5}		-35°F			x		9/30/69	
0230	9.72		3.2 x 10^{-5}		-35°F			x			
0430	9.70		4.0 x 10^{-5}		-35°F			x			
0630	9.7 -	9.3	4.0 x 10^{-5}		-35°F		x				
[illegible]745	9.48		4.9 x 10^{-5}		155°F			x			
0030	9.6		6.2 x 10^{-5}		140°F			x			
0230	9.59		7.2 x 10^{-5}		150°F			x			
0430	9.61		5.0 x 10^{-5}		135°F			x			
0630	9.65		5.4 x 10^{-5}		145°F			x			
10/1/69 1300	9.50		4 x 10^{-5}								
1743	9.48		4.7 x 10^{-5}		-35°F			x			
1949	9.48		3 x 10^{-5}		-35°F			x			
2055	9.50		2.7 x 10^{-5}		-35°F			x			
0030	9.50		2.4 x 10^{-5}		-35°F			x			
0230	9.35 -	9.45	2.5 x 10^{-5}		-35°F			Cycling			
0430	9.32 -	9.41	2.2 x 10^{-5}		-35°F			"			
0630	9.32 -	9.41	2.2 x 10^{-5}		-35°F			"			
10/2/69 1745	9.45		3.7 x 10^{-5}		155°F			x			
2040	9.45		4 x 10^{-5}		155°F			x			
0100	9.45		4.2 x 10^{-5}		155°F			x			
0300	9.45		4.6 x 10^{-5}		155°F			x			
0500	9.45		4.8 x 10^{-5}		155°F			x			
0700	9.45		4.6 x 10^{-5}		155°F			x			
TIME TO OUT VOLTAGE											
CAPACITY TO OUT VOLTAGE											

PREPARED BY /S/ Phil Woodcock